INTEGRATED ECONOMIC DEVELOPMENT AND ENVIRONMENTAL PROTECTION ASSESSMENT FOR THE MUSKEGON RIVER WATERSHED

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By

Satish Joshi

Department of Agricultural Economics
Michigan State University
East Lansing, MI 48824

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1. INTRODUCTION

To make informed decisions about proposed regional development initiatives, local policy makers and planners need information on both, direct and indirect, economic and environmental impacts of the proposed actions on the region. Any proposed activity, for example a new processing plant, has direct economic impacts in terms of employment at the plant, local income generated, local tax revenues, and indirect economic impacts through the increased output of the web of regional suppliers to the plant and their suppliers. Further, the additional local income generated results in increased consumption, which will create its own ripple effects throughout the regional economy. At the same time, the pollutant emissions from the increased direct and indirect economic activity arising from the plant affect the regional environment. Comprehensive and quantitative estimates of these effects are needed for evaluating tradeoffs between environmental and economic objectives and better community decisions. Regional planners will be most interested in local effects because they have greater jurisdiction, control and responsibility over local effects, and these local effects govern the political acceptability of their actions.

In this research we develop a web based software tool called Watershed Information Tool (WIT) that enables a comprehensive, regional economic and environmental impact assessment of development initiatives in the Muskegon River Watershed (MRW), using regional input-output analysis techniques. Input-output analysis is a well established technique for estimating the economic impacts of public policy choices. Input-output analysis models the interdependencies among various sectors of the economy by a set of linear equations and thus enables estimation of ripple effects of public policy options. Extending input-output analysis for environmental impact assessment has been proposed previously. However previous applications of environmental input-output analyses were limited in their scope due to constraints of data availability. We augment a conventional regional input-output matrix with a comprehensive environmental impact matrix, compiled by combining data from several public sources, which enables quantitative estimation of ripple effects on the environment from the increased economic activity. We develop an internet based, interactive interface for the regional input-output model of the Muskegon river watershed and the environmental impact database. The web based WIT provides a flexible tool that can be used for analyzing both economic and environmental impacts within the watershed. We also demonstrate the application of the method by evaluating a proposed dam removal project in Marion village in the Muskegon River Watershed.

This rest of this report is organized as follows: in Section 2 we provide a brief technical background on the theory and methods of input output analysis and its extensions for regional economic and environmental impact assessment; the details of the data sources and the model implementation are discussed in Section 3; in the next section, we outline the efforts we have made in disseminating the model, its application and results. Section 5 describes a detailed case study demonstrating the application of the WIT to a proposed dam removal and river restoration project in the watershed, and Section 6 concludes.

Computer screen shots of the website developed for the WIT, showing the home page, the online tutorial, the input sheets, and various outputs of the software showing the impacts of the case study project are included in the Appendix.

2. THEORY AND METHODS

2.1 Input-output analysis[1]

Input output analysis is a well established tool in economics, where the interdependencies across different sectors of the economy are represented by a set of linear equations. The core of the model is the inter-sectoral direct requirements (or technical coefficients) matrix denoted as **A**. An element a_{ij} of matrix **A** represents the dollar value of input required from sector i to produce one dollar worth output of sector j ($i = 1...n$, and $j = 1...n$). Let **X** represent the vector of total outputs of the sectors. The exogenous change in final demand for the output of these sectors is represented by a vector **F**.

Since the total output of a sector is the sum of final demand **F** and intermediate demand **AX**, (i.e. demand as input requirement for producing the output of other sectors), the input-output system can be written :

$$\mathbf{X} - \mathbf{AX} = \mathbf{F} \qquad (1)$$

The vector of total sectoral outputs required to meet a given exogenous demand **F** can be calculated by solving (1) as:

[1] This is a highly simplified exposition of input-output analysis. For a more detailed description of underlying assumptions about the structure of the economy, actual construction of national input output tables and limitations, refer to Miller and Blair 1985 and USDOC 1994.

$$\mathbf{X} = [\mathbf{I} - \mathbf{A}]^{-1} \mathbf{F} \quad (2)$$

$[\mathbf{I}\text{-}\mathbf{A}]^{-1}$ is hence often referred to as the total requirements matrix.

Closing the model with respect to households, i.e. including the households as an endogenous sector, supplying labor services as input to other sectors and purchasing outputs from other sectors for consumption, enables capturing the 'induced effects' arising from increased household consumption as a result of increased income from increased economic output.

Suppose **L** is a vector of employment coefficients, where element l_i is the direct employment in person years necessary to produce one dollar worth of the output of sector j, the direct and indirect employment effects of the exogenous demand **F** can be calculated as

$$E = \mathbf{LX} = \mathbf{L}\,[\mathbf{I} - \mathbf{A}]^{-1}\mathbf{F} \quad (3)$$

Other economic impacts of interest such as value added, personal incomes generated, or local tax revenues can be analyzed by defining **L** as the corresponding coefficient vector (e.g. lj can be indirect business tax revenues per dollar output of sector j].

The input output technique can also be extended for environmental analysis[2]. Suppose **R** is a $k*n$ matrix of environmental burden coefficients, where r_{kj} is environmental burden k (e.g. carbon monoxide emissions) per dollar output of sector j; and **B** is the vector of

[2] There is a large theoretical and empirical literature on extension of input-output techniques for environmental analysis (for example, see Ayres and Kneese 1969; Cumberland and Stram 1976; Forsund 1985; Duchin et al.1990; Duchin 1994; Lutz 1993; UN 1993)

total environmental burdens, then the economy-wide total (direct and indirect) environmental burden associated with an exogenous demand vector **F** becomes

$$\mathbf{B} = \mathbf{RX} = \mathbf{R}\,[\mathbf{I} - \mathbf{A}]^{-1}\mathbf{F} \qquad (4)$$

The environmental burden matrix **R** can include coefficient vectors for any environmental impact of interest such as energy use, non-renewable resource use, green house gas emissions etc. The contribution of individual industry sectors to the total environmental burden can be found by replacing each of the environmental burden coefficient vectors in **R**, by its diagonal matrix.

2.2 Regional input-output analysis

Traditionally, input output data collection and estimation of technical coefficient and total requirement matrices have been carried out at the national level. National input-output accounts for different counties are published periodically. For example the Bureau of Economic Analysis in the Department of Commerce, publishes annual input output accounts for the US economy as well as more detailed benchmark input output accounts once every five years(USDOC 1994, 1997, 2003). Analyses using input output techniques at the national level are common.

However, increasingly planners are also interested in assessing regional impacts. Regional economies are characterized first by high dependence on trade with ‘outside’ areas, i.e significant fractions of the regional final and intermediate demands are met by imports, and second, the local production technologies and hence the local technical coefficients might differ from the national averages. While it is possible to construct regional input output tables entirely using region specific data, primary data to enable construction of such regional tables are seldom available. Hence several methods have been developed to adjust the national tables to reflect regional characteristics, depending upon the availability of region specific information (Miller and Blair, 1985).

Suppose $\mathbf{A}^{\mathbf{R}}$ is the regional technical coefficient matrix where the element $\boldsymbol{a}^{\boldsymbol{R}}_{\boldsymbol{ij}}$ represents input from sector *i* from firms with in that region to produce a dollar worth of output of sector *j* in that region. Assuming that the local production requires the same input recipe as the national average, in order to translate the new regional demands $\mathbf{Y}^{\mathbf{R}}$ into new outputs of regional firms, $\mathbf{X}^{\mathbf{R}}$, the national coefficients matrix must be modified to $\mathbf{A}^{\mathbf{R}}$ so as to include only the inputs of regionally produced goods in local production. A common approach is to use estimated regional purchase coefficients (RPC), one for each sector in the regional economy, which shows the percentage of the total required inputs from each sector that could be expected to originate with in the region. If we denote **P** as the vector of RPCs, then the regional technical coefficient matrix would be

$$\mathbf{A}^{\mathbf{R}} = \hat{P}\,\mathbf{A} \qquad \textbf{(5)}$$

Where $\hat{P}$ is the diagonal matrix of **P**. The changes in regional output X^R required to meet regional final demand F^R are then given by

$$\mathbf{X}^{\mathbf{R}} = [\mathbf{I} - \mathbf{A}^{\mathbf{R}}]^{-1}\,\mathbf{F}^{\mathbf{R}} \qquad (6)$$

Regional economic ($\mathbf{E}^{R}$) and environmental ($\mathbf{B}^{\mathbf{R}}$) impacts associated with these changes in regional output $\mathbf{X}^{\mathbf{R}}$ can then be easily estimated by multiplying $\mathbf{X}^{\mathbf{R}}$ with economic and environmental impact coefficient matrices as in equations (3) and (4).

$$\mathbf{E^R} = \mathbf{LX^R} = \mathbf{L}\,[\mathbf{I} - \mathbf{A^R}]^{-1}\mathbf{F^R} \qquad \mathbf{(7)}$$

$$\mathbf{B^R} = \mathbf{RX^R} = \mathbf{R}\,[\mathbf{I} - \mathbf{A^R}]^{-1}\mathbf{F^R} \qquad \mathbf{(8)}$$

The elements of the economic impact matrix **L** and environmental impact matrix **R** should ideally be regional specific. However in the absence of detailed data, national values can be used as reasonable approximations. Our model uses regional values for economic impact matrix **L**, while using national averages for environmental impact matrix **R**.

The economic and environmental impacts from regional development initiatives typically arise from the local project expenditures on materials, supplies and labor expenses. We can hence, treat development initiatives as changes in the regional final demand vector equivalent to the project expenditures. These expenditures can then be allocated to appropriate input-output commodity sectors and the direct, indirect and induced effects on the regional economy and environment can be estimated using relationships shown equations (7) and (8). However equation (8) calculates only the indirect and induced effects from the inputs going into the project but not the direct environmental impacts of the project itself. These have to be estimated separately and added to the calculated estimates of indirect and induced environmental impacts. For example, if the project involves construction of a building, equation (8) allows us to calculate all the indirect environmental impacts from the production of cement, steel, wood that were used in the construction of the building, as well as the induced environmental effects from the output of consumption goods that the increased income that the project generated. However, the direct emissions and environmental impacts from the building construction activity itself have to be separately estimated and added to the effects estimated by equation (8).

3. MODEL IMPLEMENTATION AND DATA SOURCES.

We develop an integrated economic and environmental assessment model for the Muskegon River watershed in Michigan USA. Muskegon River is the longest river in the state of Michigan and feeds into Lake Michigan as shown in Figure 1. The watershed encompasses an area of 2700 square miles spread over 12 counties, covering 78 zip code areas. Muskegon River Watershed Assembly (MRWA), an umbrella organization of local county governments, planners, conservation districts, citizen and environmental groups has been actively pursuing regional economic development while protecting and improving regional environmental quality. We develop the model as a decision support tool to help MRWA and the community to make informed tradeoffs between economic development and environmental goals.

The tool has three major components: (1) a regional input-output model for the Muskegon river watershed ($\mathbf{A}^{\mathbf{R}}$), (2) comprehensive sector level economic ($\mathbf{L}$) and environmental coefficient ($\mathbf{R}$) matrices, and (3) a web based computational software combining these two, that can be used to analyze the impact of any regional development initiative.

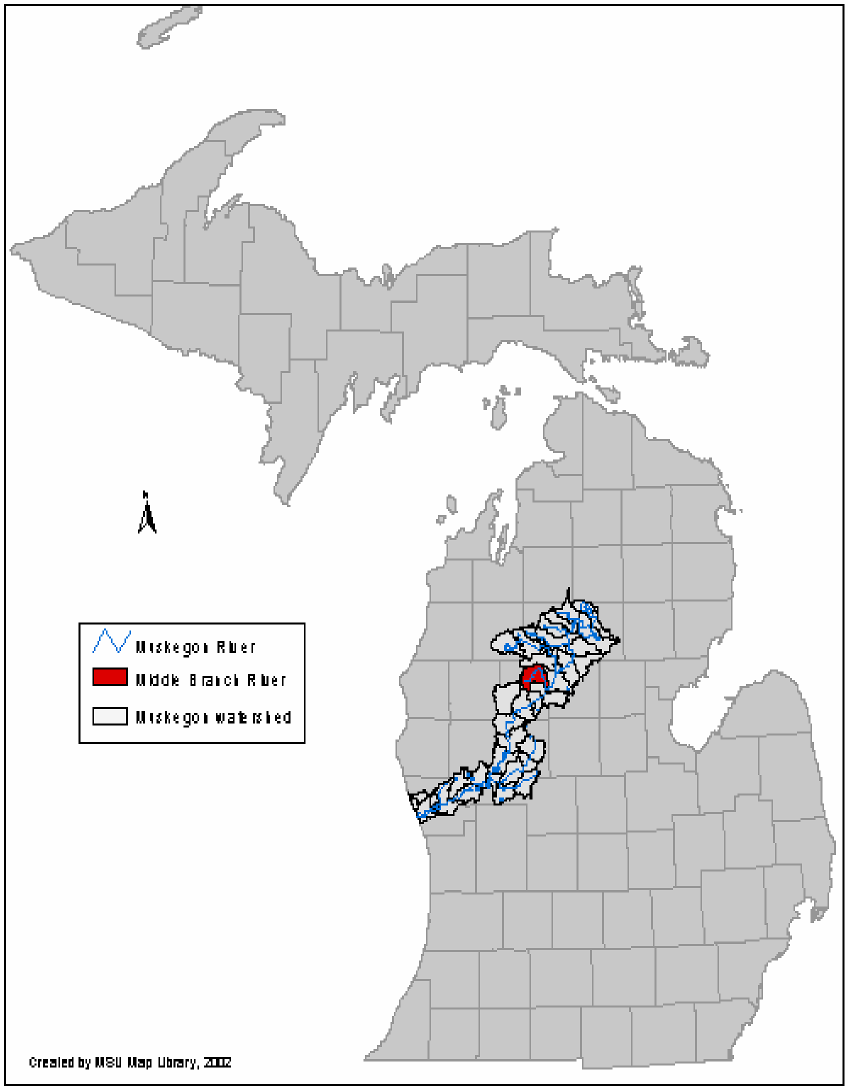

Figure 1. The State of Michigan map showing the Muskegon River Watershed**.**

3.1 Regional input-output model for the Muskegon river watershed.

We compile the regional input output model at 509 sector level detail for the Muskegon River Watershed using the methods and algorithms developed by the Minnesota Implan Group (MIG). MIG is the developer of a popular regional economic impact analysis software called IMPLAN. MIG also compiles and markets special datasets for regional economic analysis. We first delineated the boundary of the watershed using geographical information collected by the Anise Water Resources Research Center, Grand Valley State University. We initially used the US 1992 benchmark input-output tables rescaled to reflect 1997 price levels to build the first version of the model (USDOC 1997). The final version of the model is based on the 1997 benchmark input-out tables and updated with annual national input-output data for 2001. Regional purchase coefficients and the regional input-output matrix for the Muskegon River Watershed were derived using census data for the zip code areas in the watershed and MIG's econometric methods (MIG 2004).We also estimate the regional economic impact coefficients for employment, personal income generated and indirect business tax revenues using MIG's methods.

3.2 Environmental Impact Matrix

As discussed previously, the environmental impact matrix **R** is a $k*n$ matrix of environmental burden coefficients, where r_{kj} is environmental burden k (e.g. carbon monoxide emissions) per dollar output of sector j. We adapt a comprehensive environmental impact coefficient matrix initially developed by Joshi (1998, 2000) and subsequently updated and revised by researchers at the Green Design Institute, Carnegie Mellon University (GDI, 2005, Hendrickson et al 2005). The environmental impacts covered include energy use, non-renewable ores and water use, conventional air pollutant emissions, conventional water emissions, toxic releases, hazardous wastes, municipal solid waste generated, and summary indices such as greenhouse gas (GHG) emissions and CMU-ET toxicity weighted toxic releases. Table 1 summarizes the environmental impacts covered and the primary data sources and a brief discussion follows. For more details, refer to Joshi (1998, 2000), GDI (2005), and Hendrickson et al 2005.

Table 1
Data sources for the environmental impact matrix

Environmental Impact	Data Sources
Energy Consumption	Input-Output Table Work files, Census of Manufacturers, Manufacturing Energy Consumption Survey, Fuel and electricity report, US Census Bureau, Transportation Energy Data Book
Non-renewable Ore consumption	US-IO work files
Conventional Air Pollutant Emissions	USEPA's AIRS database
Water Discharges	USEPA's Permit Compliance System (PCS),
Toxic chemical Releases from manufacturing	USEPA’s Toxic Release Inventory (TRI)
Greenhouse gas emissions	Calculated from fuel/energy use data
RCRA Hazardous Waste generation	USEPA-RCRA database
Municipal Solid Waste Generation	USEPA-Office of Solid Waste
Water use	Bureau of the Census, MC82-S-6, March 1986.
External Costs	Based on air emissions and Mathews and Lave (2000)

Fuel use and energy consumption: The first version of the model used data on purchases of different fuels by the 6 digit US input-output (US-IO) sectors obtained from the work files used in preparation of the 1992 benchmark input output accounts for the U.S. economy, available from the US Department of Commerce. These work files provided data on the value of purchases of about 7000 commodities, including major fuels, by various industry sectors. The quantity estimates were based on average prices of individual fuels. The data on electricity use by the industry sectors were from the US Census of Manufactures (USDOC 1987). The total energy consumption was calculated by summing the energy content of different fossil fuels and electricity from non-fossil sources.

The final version of the model is based on the 1997 benchmark input-output tables released in 2003. However, the Department of Commerce did not release the underlying work-files to the public. As a result, we had to compile data from a number of different sources to develop sector level energy use coefficients, which was done in collaboration with researchers from the Green Design Institute, Carnegie Mellon University. The Fuel and Electric Report, U.S. Census Bureau (USCB, 2002) reports fuel and electricity usage in physical units for mineral industry sub-sectors 211 through 213 (based on the North American Industry Classification System (NAICS)) for the year 1997. Similarly, Manufacturing Energy Consumption Survey (USEIA 2002) presents fuel and electricity use at 2 digit and 4 digit industry sectors for the year 1998. The transportation energy data are from the Transportation Energy Data Book published by the USDOE (USDOE 2000). The information for other sectors is from the Annual Energy Review (http://www.eia.doe.gov/emeu/aer/overview.html). The fuels covered include coal, natural gas, LNG, LPG, motor gasoline, kerosene, aviation fuel, jet fuel, distillate fuel oil and heavy fuel oil.

Non-Renewable Ores Use: Data on value of direct purchases of various ores by different industry sectors are available in the 1992 US-IO work-files. The average producer price data for different ores from the Minerals Yearbook (USBM 1988) were used to estimate physical consumption intensities of ores by different industry sectors. We couldn't update the physical consumption intensity data for 1997 because of unavailability of IO work-files. However, we rescale these consumption vectors using producer price indices.

Criteria Air Pollutants: We use 4 digit SIC level summary data for the year 1999, from the EPA's Aerometric Information Retrieval System (AIRS) database to develop conventional air pollutant emission coefficients. These were supplemented with data from The National Air Quality and Emissions Trends Report, data for 1999 (USEPA 2001). We include emission coefficients for carbon monoxide, sulfur dioxide, nitrogen oxides, volatile organic compounds, lead, and particulate matter (PM10).

Water emissions: USEPA's Permit Compliance System (PCS) is a database that compiles data on permitted and actual water emissions of all the facilities that have NPDES permits. We obtained aggregate national emissions data at 4 digit SIC level detail for the year 2001 from USEPA's researchers, for a number of effluents. (USEPA-PCS 2005). These were used to estimate water emission coefficients for BOD (biological oxygen demand), chemical oxygen demand (COD), total suspended solids, and oil and grease. However, these represent emissions from facilities that are required to have NPDES permits. Emissions from a large number of smaller sized facilities and non-point sources are excluded. This is likely to result in significant under-estimation of water emissions. However, we haven't been able to identify good data sources to estimate emissions from these small point sources and non-point sources.

Toxic Releases: We develop sector level emission coefficients for toxic chemicals using USEPA's Toxic Releases Inventory (TRI) data for the year 2000, which includes data on toxic chemical emissions of over three hundred chemicals (USEPA-TRI 2002). Horvath and colleagues (1995) proposed a toxicity weighting scheme for aggregating TRI chemicals called CMU-ET, wherein the time weighted average threshold limit values of various chemicals relative to the threshold limit value of sulfuric acid are used as weights. The threshold limit value is the air concentration of the chemical that can not be exceeded during any 8 hour work shift of a forty hour work week, as per the occupational health guidelines of the American Conference of Governmental Industrial Hygienists (ACGIH). The CMU-ET weighting factors are included here as first level approximations to the relative toxicities and health effects of these emissions.

Green house gas emissions and Global Warming Potential: The main greenhouse gases (GHG) are carbon dioxide, methane, nitrous oxide and water vapor. The degree to which GHGs contribute to the global warming process depends on their concentration in the troposphere and on their ability to absorb the heat radiated by the earth. This absorption capacity is expressed as Global Warming Potential (GWP) relative to carbon dioxide. (IPCC 1995; Wuebbles 1995; Adriaanse 1993). GWP of different pollutants from Adiaanse (1993) are used as weighting factors in aggregating GHG emissions. The emissions of carbon dioxide, and methane from fuel combustion were estimated using U.S. EPA's AP-42 emissions factors and fuel use data discussed earlier.

Hazardous wastes: The Resource Conservation and Recovery Act (RCRA) requires all large quantity generators in the US to report the quantities of hazardous wastes generated, managed on site, received from outside sources, and shipped to off-site treatment, storage and disposal facilities. Sectoral intensities for hazardous waste generation, onsite management and off-site shipments were calculated using data from USEPA's RCRA data files for the year 1999 (ftp://ftp.epa.gov/rcrainfodata/rcra_flatfiles/)

Municipal Solid Waste: We consider municipal solid waste (MSW) mainly as a waste stream related to consumption, unlike the other emissions which are a function of outputs from production sectors. We assume that the quantity of MSW generated is directly proportional to the increase in personal income. We use the data on national MSW generation and its composition for the year 2001 from a study conducted by Franklin Associates (USEPA 2003). We normalize the quantities of total MSW generated and its components: paper, wood, metals, glass, etc, by the national personal income for the year 2001, which was $8.43 trillion to obtain MSW coefficients.

Water use: The water use data are from a fairly old study conducted by the U.S. Department of Commerce in 1982. (USDOC 1986). More recent data at the level of individual industry sectors are unfortunately not available.

External costs: We calculate external costs from conventional air pollutant emissions using social cost estimates of pollution damage from the economics literature. Detailed information on these values is available from the article by H. Scott Matthews and Lester B. Lave (2000).

General notes on the environmental impact data

Following are some general notes and caveats on the assumptions and approximations used in estimating the environmental impact coefficients.

- All the estimates of the environmental impact coefficients are based on national aggregate data on emissions, industry sector outputs and personal income. Hence these are national averages. We could not get region specific or even state level data at the detail of individual industry sectors for most of the environmental impacts. However, USEPA has an ongoing project called the Trade and Environmental Assessment Model (TEAM), which aims to develop sector level emissions coefficient data at the level of individual counties (Creason and Stone, 2004). We plan to incorporate these detailed county level data, when they become available.
- The environmental data are from different sources and for different periods. We have normalized the emission data by deflating sector output data with appropriate producer price indices and then rescaling them to the year 2001. This normalization and rescaling will add some uncertainty and error.
- BEA changed its industrial classification system from the Standard Industry Classification (SIC) to North American Industrial Classification System (NAICS) beginning with the 1997 Benchmark input-output tables. However, most environmental data from DOE and USEPA are still on the basis of SIC. Similarly IMPLAN has its own sectoring scheme, which currently is mostly based on NAICS, except for a few agriculture and tourism related sectors. A large number of sectors are common across the three systems. However NAICS is a major reorganization and there is not an exact one to one correspondence between NAICS, SIC and IMPLAN

sectors. We have matched and created bridge tables for NAICS, SIC and IMPLAN sectors to the extent feasible. But, some assumptions and approximations were necessary and resulting uncertainties remain. However, this is likely to be a transitional problem, as DOE, EPA and IMPLAN systems will switch over to NAICS in the near future. Future updates will suffer less from these approximations.

- Many of the environmental emissions data are underestimated mainly because, regulations require reporting by relatively larger facilities only. For example, our water emissions data is limited to firms that are required to obtain NPDES permits. Similarly, GAO estimated that the toxic release inventory data seriously under-estimates the actual releases, and reported toxic releases might be as low as 5% of actual releases (USGAO, 1991). Our external cost estimates are limited to valuation of health effects from air pollutant emissions only.
- USEPA has carried out major revisions to their databases like AIRS and PCS since the initiation of this project. As a result many of the data sources which were downloadable previously are no longer available or organized differently. Similarly US Department of Commerce has stopped making the US-IO work-files available publicly. These changes have resulted and will result in difficulties in updating some of the data in the future.

3.3 Software development

The third component of the project is developing a user-friendly and flexible software that combines the regional output model and the environmental impact database with interfaces for user input, and report generation using the model output. We had proposed a stand-alone personal computer based software in the initial grant application, and developed such a stand-alone software in the first phase of the project. However, we felt that an internet based version of the tool will be more useful for three reasons.

(1) It can be made available to a wider audience more easily.

(2) The internet based tool will be easier to use, because difficulties of installation, computer power/memory requirements, operating system compatibility etc. can be avoided.

(3) Updates and troubleshooting would be easier, since all can be handled centrally here at MSU.

Hence in the third year of the project, we focused on developing an internet version. The final version of the WIT is a completely internet based tool, located on a server at the Department of Agricultural Economics, Michigan State University, and currently available to the public at www.aec.msu.edu/dbtest/test/default.htm.

The regional input-output model and the environmental impact matrices form the back end database supporting the model. These data, specifically the regional input-output matrix $\mathbf{A^R}$, the local economic impact matrix $\mathbf{L}$, and the environmental impact matrix $\mathbf{R}$ as in equations (7) and (8) are stored in a Microsoft Access database. The user provides project specific details, which is essentially involves specifying the final demand vector $\mathbf{F^R}$. The software has a dynamic HTML Java-script based user interface, allowing the user to search for appropriate economic sectors, choose the year of the data, and then input the project cost estimates.

These model algorithms programmed as SQL queries in ADO, use input data i.e. the user specified $\mathbf{F^R}$, the underlying Access database, and the equations (7) and (8) to calculate regional economic and environmental impacts of the project. The user can specify if she wants to include induced effects, i.e. endogenize the household sector in the impact assessment, by clicking on a radio button. The software can then generate a number of specific reports, e.g. a summary report, detailed reports on specific economic impacts, such as employment generated, or on a specific environmental impact, say conventional air pollutants or greenhouse gas emissions. The user can specify the reports that she is interested in by clicking on the appropriate radio buttons. Within the individual reports, the user can choose to display either all the sectors or only selected top contributing sectors. Similarly, users can sort the results based on a specific subset of environmental impacts. The software also allows the users to save their results. All these report generation utilities are auto-generated scripts coded in ASP.

3.5 Model Website

We have developed a website www.aec.msu.edu/dbtest/test/default.htm to make the model available for public use. In addition to the model itself, the website provides some background information on the project and the Muskegon river watershed, a brief description of the methods used in the model, and an on-line tutorial for using the model. The on-line tutorial provides step by step instructions with associated computer screen shots at each step. Links to the full project report and detailed case study are also included. In addition, to help collect information on who uses the model, we have created a user registration utility. The utility assigns user id and password to the users who register and then provides access to the model after they login using the provided user id and password. The appendix at the end of this report includes screen shots of the home page, a blank input page, completed input page for the case study, output selection page, and selected output reports of the case study.

4. DISSEMINATION

We have made significant efforts to disseminate information about the research project and its results to local decision makers and community groups. We have presented the project details and results at a legislative round table and public meeting held at Muskegon on August 1, 2002. We presented the initial versions of the tool at the annual research conferences of the Muskegon River Watershed Partnership held in 2002, and 2003. We conducted tutorials on how to use the internet based WIT, with example applications at The 3rd Annual Conference of the Muskegon River Watershed (Partnership) Initiative, held on April 26, 2004 in Big Rapids. Over 40 local decision-makers and community leaders of Muskegon Watershed attended the two tutorial sessions. The participants also provided useful feedback on the tool, which was incorporated in the final version of the WIT. We have also made several informal presentations at various local village meetings, and meetings of the Muskegon River Watershed Partnership.

A video interview discussing this project has been included as a part of an hour long video about the Muskegon River and conservation efforts in its watershed produced by the Muskegon River Watershed Assembly. The video premier was attended by over 100 people including several legislators. This video is being distributed to public TV stations and local agencies in Michigan. The Muskegon River Watershed Assembly has created a repository of all available information on the watershed at www.mrwa.org. A link to the internet WIT site is provided on the repository web site.

A paper titled**, "***Analyzing Life-cycle Environmental Impacts of Local Development Initiatives Using Regional Economic and Environmental Input-Output Models*," summarizing the WIT and the results from a case study of a proposed dam removal in Marion village were presented at the *International Conference on Life Cycle Assessment and Management*, held in Seattle (Sept 22-25, 2003). For details see http://www.lcacenter.org/InLCA-LCM03/index.html and http://www.lcacenter.org/InLCA-LCM03/Session-IO-CaseStudies.html. An article for publication in a peer reviewed academic journal is under preparation.

A MS thesis titled "*Evaluation of Economic Benefits and Impacts of Dam Removal: A Case Study of the Proposed Removal of the Marion Dam on the Middle Branch River, Osceola County, Michigan"* was completed by Tsitsi Makombe, a graduate student in the Department of Agricultural Economics, Michigan State University. She defended her Master's thesis in August 2002 (Makombe, 2002). The thesis is based on an initial version of the WIT, where only the economic impact analysis module was completed, but the environmental impact database was still under construction.

5. CASE STUDY: MARION VILLAGE DAM REMOVAL PROJECT[3]

In this section, we demonstrate the use of the model and the software by applying it to analyze the economic and environmental impacts of a proposed dam removal project in Marion village, Osceola County, within the Muskegon river watershed.

5.1 Michigan Dams

The state of Michigan has over 2,000 dams on its waterways. Most of the dams were built for recreational purposes. State and Federal agencies in Michigan regulate all dams that are at least 6 feet high and create reservoirs of at least 5 acres. The Marion Dam is one of the 95 dams located in the Muskegon River Watershed. A fourth of the dams in the watershed are now more than 50 years old, have become obsolete and violate environmental laws (Muskegon Chronicle 1999). Several dams in Muskegon River Watershed, including the Marion Dam, violate Michigan's surface water quality standards by increasing water temperatures by more than 2 degrees Fahrenheit (MDNR 1997). State biologists with the Department of Natural Resources have suggested addition of fish ladders and removal of dams to improve water quality in Michigan's rivers.

5.2 Marion Dam

The Middle Branch River is a 33-mile long tributary of the Muskegon River (see Fig 2, and Fig 3). The Middle Branch River runs through the village of Marion, in Osceola County and the river was first impounded in 1893 to generate hydroelectricity for the logging industry that was in the area. The impoundment of the river- the Marion Mill

[3] Parts of this case study draw on Makombe (2002)

Pond, is spread over 26 acres and is found almost halfway between the headwaters of the Middle Branch River and its confluence with the Muskegon River. The difference in the elevation between upstream and downstream of the dam is approximately 8 feet. The Middle Branch River is designated a coldwater trout stream by the Michigan Department of Natural Resources (MDNR) (MDNR 1997). The river enters the pond from the northeast and flows for about 2100 feet towards the dam spillway (See Fig 5). Next to the spillway is a 3-4 feet-wide fish ladder. There are two other water outlets from the pond, but only one of these can be used to regulate pond water levels. The dam and the pond have been the center of recreational activity ever since the logging industry ceased operating. Marion dam is classified as a dam with a significant hazard potential by the Michigan Department of Environmental Quality (MDEQ).4

5.3 Ecological Condition of the Middle Branch River

Based on sensitivity to temperature, conductivity, and trout densities, the Middle Branch River is in a critical condition according to the MDNR(1999). Thermal pollution is a major threat posed by the Marion Dam. Temperatures most favorable for fisheries in cold water streams range between 46 to 60° F. Temperatures beyond 69°F can have dire consequences for cold water species (Allan 1995). Michigan's Surface Water Quality Standard for the Middle Branch River is 68°F. Mean summer temperatures downstream of the Marion Dam on Middle Branch River have often exceeded 69° F (Lessard 2000).

[4] "Significant hazard potential dam means a dam located in an area where its failure may cause damage limited to isolated inhabited homes, agricultural buildings, structures, secondary highways, and shoreline railroads, or public utilities, where environmental degradation may be significant, or where danger to individuals exists"- Michigan Department of Environmental Quality.

Water temperatures downstream of the Marion dam have also been shown to violate Michigan's surface water quality standards of not exceeding 2°F. Table 2 shows mean summer temperatures in the MBR over the course of 4 years. This shows how water temperatures are generally higher by about 7°F, below the impoundment compared to upstream of the impoundment. Coldwater fish densities for brook trout, brown trout, and slimy sculpin have been found to be much lower downstream than upstream due to increased water temperatures below the impoundment (Lessard 2000). At present there are minimal recreational activities taking place along the river and in the pond due to sediment accumulation in the pond. Progressive AE (2001) found the Mill pond to be shallow with an average depth of 3 feet from the surface to the top of soft sediment, and hence did not support viable fish populations.

5.4 Project Description

MDNR has proposed removing the Marion dam as a way to restore the Middle Branch River to its free-flowing status. The restoration proposal developed by the Marion village plans to replace the reservoir created by the dam, with an artificially created pond while removing the dam. The goals are not only to improve coldwater fishery along the stream, but also to, create a warm water fishery in the pond, to improve other recreational opportunities for swimming and boating, and to protect property values around the

Fig 2**.** Osceola County, Michigan

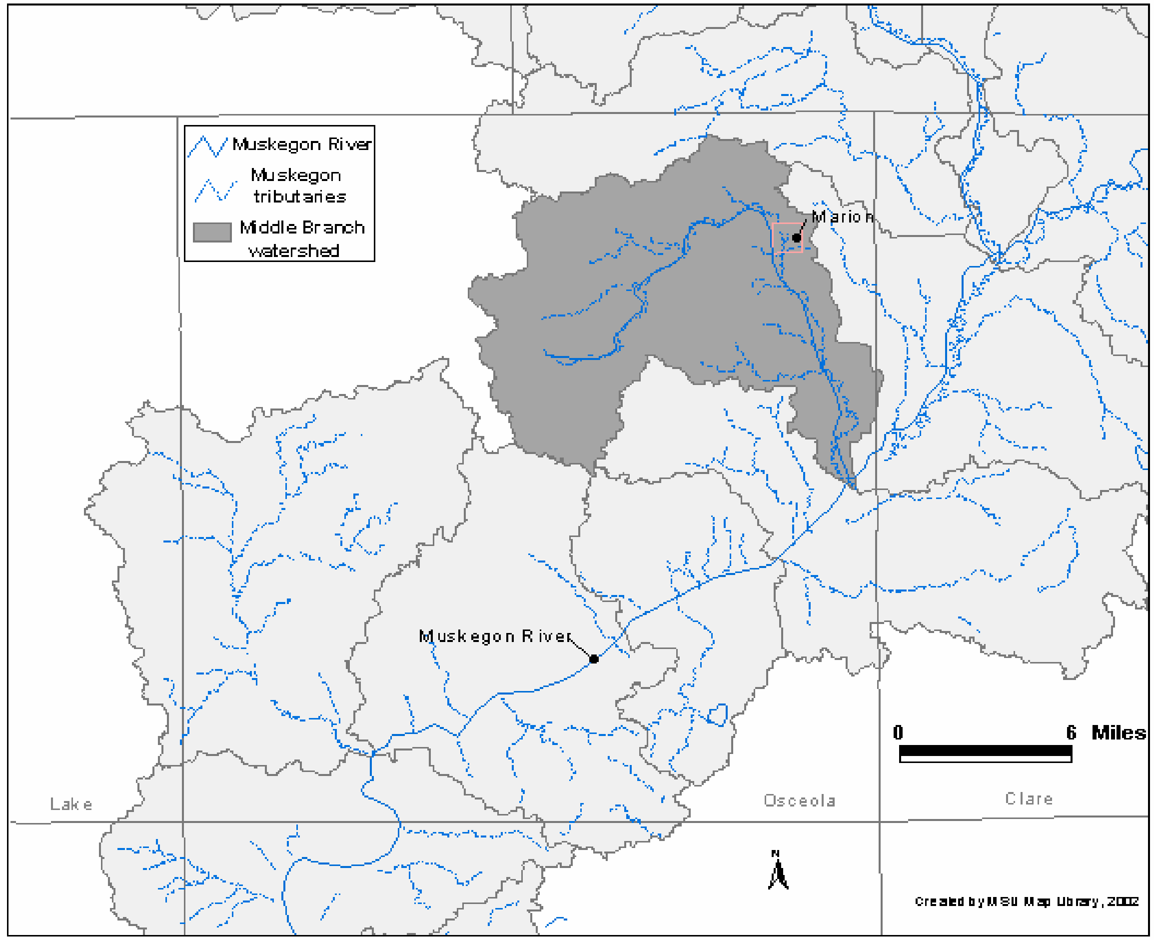

Fig 3. Middle Branch River Watershed, Osceola County, Michigan

Table 2: Mean Water Temperature for Middle Branch River Upstream and Downstream of the Marion Impoundment		
Location	**Year**	**Mean Water Temperature (degrees F)**
Upstream	1998	60.7
Downstream	1998	68.3
Upstream	1999	59.3
Downstream	1999	65.2
Upstream	2000	57.7
Downstream	2000	64.8
Upstream	2001	61.2
Downstream	2001	68.1
Source: O'Neal, 2002		

current reservoir. The Marion proposal hence, includes the following additional components:

- Construction of an earthen dike that separates the river from the pond.
- Deepening the pond to about 25 feet, by dredging, to increase fishery and recreational opportunities.
- As separating the pond from the river means that the pond will not have a fresh water supply, a gravity flow system that would channel water from the river to the pond is proposed.
- Lining the river with stone to create white water conditions and to decrease erosion at the current site of the dam.

- Construction of a small bridge at the present location of the dam to provide a fishing platform and passage.
- Two sediment traps to prevent sediment transportation downstream when the dam is removed.

Figure 4 is a diagram depicting the proposed restoration project put together by Progressive Architectural Engineering (PAE 2001). The cost estimates are shown in Table 2.

5.5 Evaluation of Economic and Environmental Impacts of the project.

Any project such as the Marion dam removal will have two kinds of impacts: first the impacts due to the project related initial construction and investment activities; and second the impacts from ongoing activities resulting from the project. In the specific case of the Marion project, impacts arise from the initial expenditures in the dam removal and restoration activities, and once the dam is removed there will be impacts from ongoing activities such as increased fishing. We estimate these impacts separately.

5.6 Impacts from dam removal and restoration activities.

As Table 3 shows, the estimated cost of the dam removal and restoration is $4.29 million consisting of $2.03 million in direct labor costs, and $2.26 million in materials and services. We estimate the economic environmental impacts from this expenditure using the WIT software. However, in order to use WIT, we need to recast the project cost estimates in terms of specific material and service inputs that can be expressed as outputs of different input-output sectors. Table 4 shows the project cost estimates recast by identifying value of specific material and service inputs and corresponding input-output sectors. This recasting was done in consultation with engineers from Progressive Architectural Engineering Inc. As can be seen, the major purchases are machinery and equipment rentals ($804,750), architectural and engineering services ($514,500), dimension stone ($284,000), and sand and gravel ($165,527). Table 4 is essentially in the exact format of the project cost sheet that has to be input into the WIT.

The WIT then calculates the economic and environmental impacts of these expenditures on the Muskegon river watershed region. It is important to note that, if any of these inputs, for example, steel reinforcement bars are not being produced within the watershed, increased final demand for steel reinforcement bars will have no local impacts on the watershed, because all the increased rebar production occurs outside of the watershed. Similarly, in calculating induced impacts, i.e. impacts from increased local personal consumption expenditures arising from increase in local wage compensation, we need to estimate how much of the project related labor compensation, is likely to be paid to locals. Based on the average wage rate in the Muskegon river watershed of $39,370 per year, the total employment in the project would be 51.3 full time equivalent jobs. Based on our discussions with the project engineers, we estimated that only 21 of these employees are likely to come from within the watershed and hence the associated increase in local employee compensation will be $826,770. We use these compensation numbers is estimating local economic and environmental impacts. The software input screen with these inputs is shown in the Appendix (Figures A8, A9).

Diagram of Project Restoration

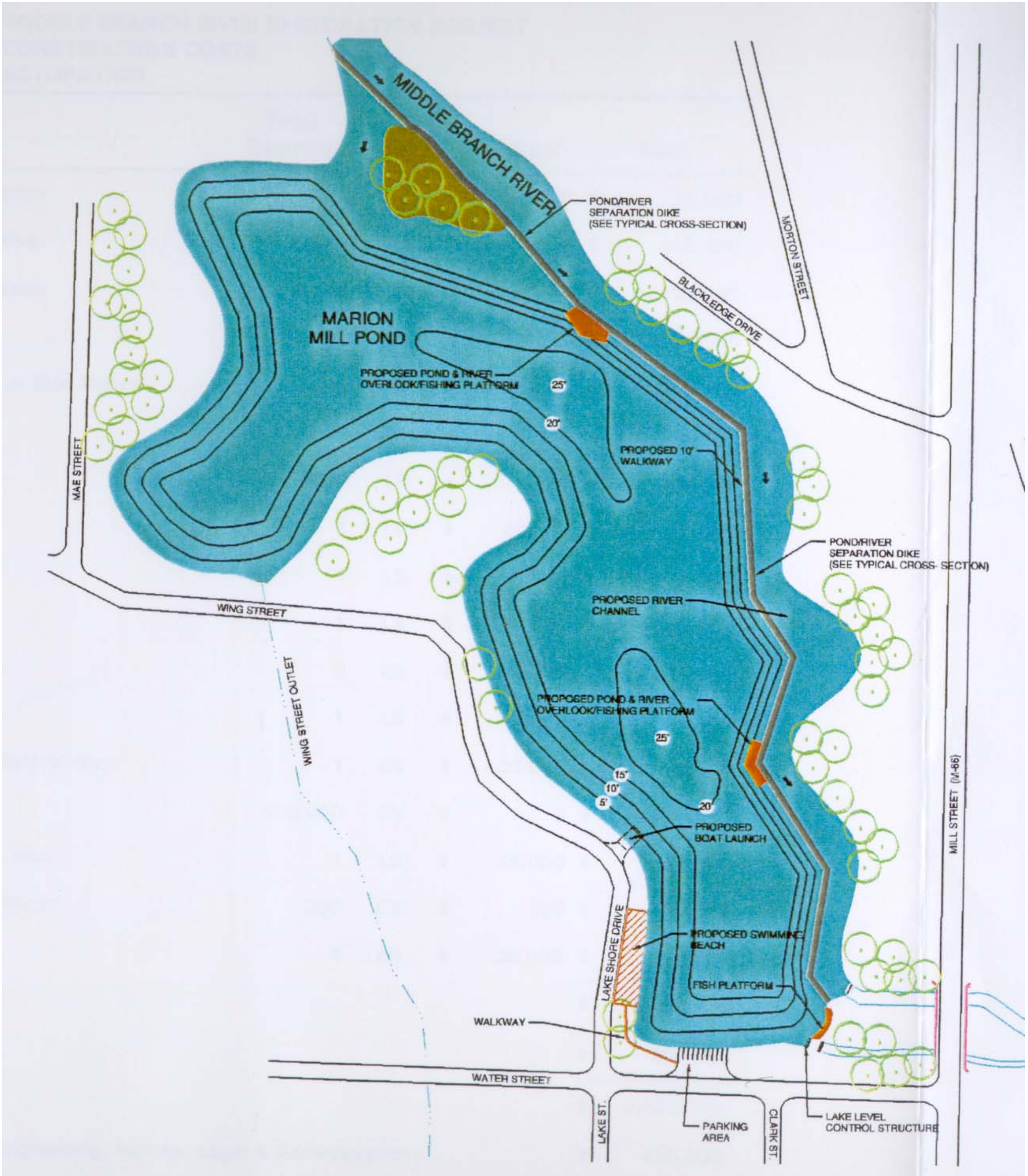

Figure 4. Marion Mill Pond and Middle Branch River Restoration Project Site Plan
Source: Progressive Architectural Engineering, 2001.

Table 3: Cost Estimations for the Middle Branch River and Marion Mill Pond Restoration Project and Recreation Elements

No	*Project Components*	**Total Quantity**	**Unit**	**Unit Cost**	**Cost**		**Breakdown of costs Labor**		**Materials**	
(Group 1) Middle Branch River Restoration Elements										
1	Mobilization/Demobilization	1	LS	$25, 000	$	25,000	$	18,750	$	6,250
2	Dredging/Disposal for River	25,000	CY	$6	$	150,000	$	75,000	$	75,000
3	Dredging/Disposal for Berm	20,500	CY	$6	$	123,000	$	61,500	$	61,500
4	Berm Fill	27,300	CY	$10	$	273,000	$	90,090	$	182,910
5	Stone Riprap w/Fabric on Side Slopes	7,100	CY	$100	$	710,000	$	355,000	$	355,000
6	Dam Removal	1	LS	$200,000	$	200,000	$	180,000	$	20,000
7	Sand Trap Construction	2	LS	$ 10,000	$	20,000	$	18,000	$	2,000
8	Sand Trap Maintenance	1	LS	$30,000	$	30,000	$	27,000	$	3,000
9	Restore exposed River Bank/Bottom	1	LS	$30,000	$	30,000	$	24,000	$	6,000
10	Boulder/Rock in River Channel	200	CY	$150	$	30,000	$	6,000	$	24,000
	Construction Total				$	1,591,000			$	735,660
	Contingencies (10% of Construction)				$	159,100			$	159,100
	Engineering, Permits, Legal, & Administrative (15% of Construction)				$	238,650			$	238,650
	Total				**$**	**1,988,750**	**$**	**855,340**	**$**	**1,133,410**
(Group 2) Marion Pond Restoration Elements										
1	Pond Inlet Structure	1	LS	$20,000	$	20,000	$	5,000	$	15,000
2	Pond Outlet Structure	1	LS	$15,000	$	15,000	$	3,750	$	11,250
3	Pond Dredging/ Disposal	400,000	CY	$4	$	1,600,000	$	1,104,000	$	496,000
	Construction Total				$	1,635,000			$	522,250
	Contingencies (10% of Construction)				$	163,500			$	163,500

Appendix 2 (cont'd).

Table 3 (Continued)

No	Events	Total Quantity	Unit	Unit Cost	Cost		Breakdown of costs Labor		Materials	
	Engineering, Permits, Legal, & Administrative (15% of Construction)				$	245,250			$	245,250
	Total				**$**	**2,043,750**	**$**	**1,112,750**	**$**	**931,000**
(Group 3) Recreation Elements										
1	Asphalt Walkway	2,400	SY	$10	$	24,000	$	9,600	$	14,400
2	Guard Rail	4,200	LF	$25	$	105,000	$	21,000	$	84,000
3	Boat Launch/Swimming Area	1	LS	$15,000	$	15,000	$	4,950	$	10,050
4	Bridge Over River	1	EA	$30,000	$	30,000	$	9,900	$	20,100
5	Fishing Platforms	3	EA	$10,000	$	30,000	$	9,900	$	20,100
	Construction Total				$	204,000			$	148,650
	Contingencies (10% of Construction)				$	20,400			$	20,400
	Engineering, Permits, Legal, & Administrative (15% of Construction)				$	30,600			$	30,600
	Total				$	255,000	**$**	**55,350**	**$**	**199,650**
					$	4,287,500				
							$	**2,023,440**	**$**	**2,264,060**
	Project Total								**$**	**4,287,500**

Source: Progressive Architectural Engineering, 2001

Table 4: Project Cost estimates and Corresponding Input-Output Sectors

Input-Output Sector	**Cost $**	**Notes**
Direct Labor(employee compensation	2,023,440**	Labor expense for all components
Machines and equipment rental and leasing	804,750	Leasing of equipment for dredging, dam removal and construction
Stone mining and quarrying	284,000	Stones for riprap and lining
Other new construction	349,250	Mobilization, demobilization and contingency expenses were assumed at other new construction cost structure
Sand and gravel	165,527	Berm filling
Ready mix concrete	28,920	Boat lunch, fishing platform etc.
Other concrete manufacturing	19,688	Pond inlet and outlet structure construction
Iron and steel pipe from purchased steel	67,200	Guard rails along walkway
Iron and steel mills	2,625	Rebars for pond inlet outlet structures
Engineered wood and truss manufacture	16,080	Bridge structural members
Asphalt paving mixture and block manufacturing	11,520	Asphalt walkway paving
Architectural and engineering services	514,500	
TOTAL	**4,287,500**	

****** Note that the estimated local compensation is only $826,770 as discussed in the text.

Table 5 shows a summary of the economic and environmental effects on the Muskegon river watershed from the one-time expenditures on the Marion dam removal and river restoration project, as estimated by the WIT. The table shows only a summary of select environmental impacts. The software generates more detailed data on individual components of these impacts, for example WIT estimates toxic releases to air, water, land etc. Similarly low, median and high values of external costs, various fuels in energy consumption, are calculated. Also, data on contributions of the individual input-output

Table 5: Economic and Environmental Impacts on Muskegon River Watershed of the Marion Dam Removal and River Restoration Project (initial project expenditures)

Impact Category	Impact sub category	Unit	Impact without Induced effects	Impact including Induced Effects
Economic Impacts				
Total economic output increase		$ Mil	2.182	3.005
Total employment generated		Ann.FTE	45.88	53.06
Increase in local personal Income		$ Mil	1.831	2.170
Increase in Indirect business taxes		$ Mil	0.062	0.125
Environmental Impacts				
Criteria Air Pollutants	Total air pollutants	MT	14.041	18.665
	SO_2	MT	1.390	2.250
	CO	MT	6.118	8.599
	NO_2	MT	5.202	5.883
	Lead	MT	0.037	0.110
	Particulates PM_{10}	MT	0.404	0.544
Water emissions (NPDES)	Total	Kg	1039.935	6397.117
	BOD (5 day)	Kg	49.460	359.791
	COD	Kg	3.745	7.344
	Total Suspended solids	Kg	977.072	6016.694
	Oil and grease	Kg	9.658	13.288
RCRA Hazardous Wastes	Generated	MT	162.560	180.781
	Managed	MT	29.803	34.173
	Shipped	MT	5.895	6.830
Toxic Releases Unweighted	Total releases & transfers	MT	0.145	0.186
	Releases to Air	MT	0.054	0.075
	Non-Air Releases	MT	0.091	0.111
Total Toxic Releases (weighted)	Total	CMU-ET MT H_2SO_4 eq	0.035	0.079
	Releases to Air	-do-	0.003	0.004
	Non-Air Releases	-do-	0.0.32	0.075
Greenhouse gases	CO_2	MT	385.695	798.588
	Total GWP (CO_2 eq)	MT	459.00	953.299
Energy use	Total	TJ	6.143	9.935
	Electricity	MKwh	0.255	0.350
	Coal	TJ	0.779	2.242
	Natural gas	TJ	0.500	2.877
	Motor Gasoline	TJ	0.408	0.593
Municipal Solid Waste	Total	MT	45.67	54.15
	Paper	MT	17.08	20.26
	Metals	MT	3.55	4.21
	Glass	MT	2.48	2.95
Water use	Intake (Total)	Bil gal	0.0002	0.0004
Safety	Total fatalities	Number	0.0008	0.0011
External costs	Median air pollution related	$ mil	0.0156	0.0231

sectors to the totals displayed in Table 5 are also available. The Appendix has detailed screen prints showing various output reports from this particular run of the model estimating these impacts, which reveal the additional details available in the model output (Figures A9 to A18).

5.7 Impacts from ongoing activities as a result of the dam removal project

The main environmental/ecological benefit from the dam removal project is restoration of the downstream portion of the Middle-branch River as a cold water fishery stream. We assume that additional 16 miles of cold water fishery stream in Osceola County will be available for angling, as a result of the project. Availability of these additional 16 miles of cold water fishing stream is likely to affect angler behavior in two ways: first many of the current anglers fishing elsewhere in the state are likely to switch to Middle Branch River; second, some locals will take up angling because of availability of a convenient fishing stream. As a result, local fishing trips made to Osceola county are likely to increase. The ongoing local economic benefits from project arise from the expenditures that anglers make on purchasing goods and services such as lodging, food, fishing supplies etc while on their fishing trips. These purchases and associated local economic activities also create their own environmental impacts.

In order to estimate these economic and environmental impacts, we first need to estimate the changes in the angling trips made to the county as a result of the project, then estimate expenditures associated with these trips, and then use the WIT software to estimate overall effects including indirect effects of these expenditures on the watershed. We estimate the changes in fishing trips made to Osceola County using the Michigan Angling Demand Model (MADM).

5.8 Michigan Angling Demand Model

The MADM, developed by Hoehn and others (1996), estimates the demand for recreational fishing in Michigan. The MADM uses a multiple site travel cost method (TCM). Travel cost models are based on the notion that visitors to an environmental amenity site incur economic costs in the form of time and travel expenses, and that these costs can be used to infer economic values placed on these amenities by visitors to the site (Perman, et al, 1996). The two main types of travel cost models are single site and multiple site models (Lupi, 1998). The single site TCM estimates the value of recreational fishing at a single site. Multiple site travel cost models incorporate the idea that visitors can choose among alternative recreational sites.

The MADM is a multiple site model that employs a nested the Random Utility Model (RUM). It models choices among different types of fishing opportunities available in the state of Michigan namely, between single day or multiple day trips, choice among fishery types such as, Great Lakes warm water, Great Lakes cold water, inland warm water rivers, inland cold water rivers, inland cold water lakes, inland warm water lakes, or anadromous runs, and choice among sites in various counties of Michigan. MADM uses behavioral data obtained through a survey of Michigan residents identified to be potential anglers (Hoehn 1996), and data on site characteristics obtained from creel surveys conducted by the MDNR. Site characteristic variables used in the model include, catch rates (used only for the warm and cold water Great Lakes fisheries), stream miles by quality class for both warm and cold rivers/streams, and lake acreage for warm and cold lakes. The RUM estimates the drivers of choice of a given recreational site from a set of alternative recreational sites. The estimated model parameters in MADM can be used to predict how the demand for recreational fishing, i.e. number of visits made to particular site varies with changes in site characteristics, after taking into account all the substitutions across available sites.

The Marion project is expected to restore 16 miles of the Middle-Branch River from a secondary quality cold water fishing stream to a top quality cold water fishing stream. We use MADM to estimate the changes in fishing trips made to the Muskegon River Watershed as a result of availability these additional 16 miles of top quality cold water fishing stream. Table 5 shows the results from the MADM model estimations[5].

As Table 6 shows, the restoration project results in an increase of 432 single day trips, and a substantial substitution of inland lake warm water trips (-184), within the watershed. Total recreational fishing days in the watershed will increase by 1,390 per year.

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[5] For more details on the estimation procedure, and additional estimation results on the gains in consumer welfare at county, watershed and the state levels, refer to Makombe (2002). Also, because the unit of geographical analysis in MADM is a county, we approximate the Muskegon River watershed by the 13 counties it covers.

Table 6: Estimated changes in fishing trips and user days by angling type, as a result of the change in status of 16 miles of the Middle-Branch River, from secondary quality to top quality

Product Line	**Single Day Trips** Before 16 mile Change	After 16 mile Change	Change	% Change	**Multiple Day Trips** Before 16 mile Change	After 16 mile Change	Change	% Change	**Change in Total User Days***
Great Lakes warm	48,064	48,061	(3)	(0.01)	5,664	5,663	(1)	(0.02)	(7)
Great Lakes cold	20,492	20,491	(1)	(0.00)	8,863	8,861	(2)	(0.02)	(9)
Inland lake warm	413,795	413,611	(184)	(0.04)	111,638	111,611	(27)	(0.02)	(288)
Inland lake cold	18,755	18,749	(6)	(0.03)	3,997	3,995	(2)	(0.05)	(14)
River Stream warm	84,279	84,240	(39)	(0.05)	13,962	13,960	(2)	(0.01)	(47)
River Stream cold	48,051	48,483	432	0.90	28,755	29,106	351	1.22	1,783
Anadromous runs	59,210	59,196	(14)	(0.02)	21,133	21,129	(4)	(0.02)	(29)
Totals	**692,646**	**692,831**	**185**	**0.74**	**194,012**	**194,325**	**313**	**1.07**	**1,390**

Negative figures in parentheses

*User days are defined by multiplying multiple day trips by 3.85 and adding single day trips, 3.85 is the average length of a multiple day trip.

5.9 Economic and environmental impacts of increased recreational fishing trip expenditures

Estimation of economic impacts associated with increased recreational fishing days, requires information on how much anglers spend on an average fishing trip. We use expenditure information from the from the U.S. Department of Interior's 1996 National Survey of Fishing, Hunting and Wildlife Associated Recreation (USDOI, 1996). Table 7 shows average angler expenditures by Michigan residents per trip to freshwater fisheries. We calculate the expenditures per trip by dividing the amounts spent on different trip items e.g. food by the number of freshwater trips made by state residents. Table 6 also shows the total increase in expenditures associated with the increase of 1390 recreational fishing days within the watershed. We assume that all these incremental purchases occur within the watershed, though it is likely that some of these items will be bought outside the watershed.

Table 7: Fishing days, expenditures and input output sectors

Expenditure item	Exp per day in 1996 dollars (USDOI, 1996)	Total Expenditure for 1390 fishing days	Corresponding input-out sector in WIT
Food	$4.25	$5907.50	Food services and drinking places
Lodging	$4.25	$5907.50	Hotels and motels
Transport	$5.04	$7005.60	Petroleum refineries
Other trip costs	$7.44	$10341.60	General merchandise stores
Total	$20.98	$29162.20	

We estimate the economic environmental impacts from these ongoing yearly expenditures using the WIT software. However, in order to use WIT, we need to express these expenditures as increase in final demand for outputs of different input-output sectors. Table 7 also shows the input-output sectors associated with these expenditures.

Table 8 shows a summary of the annual economic and environmental effects on the Muskegon river watershed from the on-going expenditures from increased fishing days resulting from the Marion dam removal and river restoration project, as estimated by the WIT. As can be seen, these ongoing annual impacts are small compared to the one-time impacts from the initial capital expenditure. Annual fishing related expenditures of $32,046 in 2001 dollars (or $29,162 in 1996 dollars) lead to an increase in local output by $26,000, local employment by 0.571 FTEs and local personal income by $11,000. The environmental impacts as shown in Table 7 include total air emissions of 0.09MT, RCRA hazardous wastes 0.29 MT, and 0.27 MT of MSW.

Results shown in Tables 5 and 8 provide information on economic and environmental impacts of both the initial capital expenditures and the ongoing activities resulting from the Marion river restoration project. These provide valuable information to the local community and decision makers in evaluating the project and in assessing the benefits and costs of the project. While WIT does not provide all the information necessary for decisions, it can be a valuable tool in enabling informed decisions. The method illustrated by the case study can also easily be applied to any local development initiative.

Table 8: Economic and environmental impacts on Muskegon River Watershed from the increased annual expenditures on fishing trips resulting from river restoration

Impact Category	Impact sub category	Unit	Impact without Induced effects	Impact including Induced Effects
Economic Impacts				
Total economic output increase		$ Mil	0.0196	0.026
Total employment generated		Ann.FTE	0.506	0.571
Increase in local personal Income		$ Mil	0.009	0.011
Increase in Indirect business taxes		$ Mil	0.002	0.002
Environmental Impacts				
Criteria Air Pollutants	Total air pollutants	MT	0.0544	0.0913
	SO_2	MT	0.0124	0.0191
	CO	MT	0.0251	0.0442
	NO_2	MT	0.0111	0.0164
	Lead	MT	0.0017	0.0022
	Particulates PM_{10}	MT	0.0017	0.0028
Water emissions (NPDES)	Total	Kg	12.599	54.220
	BOD (5 day)	Kg	1.8725	4.2849
	COD	Kg	0.0370	0.0650
	Total Suspended solids	Kg	10.6484	49.799
	Oil and grease	Kg	0.0414	0.0696
RCRA Hazardous Wastes	Generated	MT	0.1452	0.2867
	Managed	MT	0.0441	0.0781
	Shipped	MT	0.0384	0.0456
Toxic Releases Unweighted	Total releases & transfers	MT	0.0005	0.0008
	Releases to Air	MT	0.0003	0.0005
	Non-Air Releases/transfers	MT	0.0002	0.0003
Total Toxic Releases (weighted)	Total	CMU-ET MT H_2SO_4 eq	0.0002	0.0005
	Releases to Air	-do-	0.0000	0.0000
	Non-Air Releases/transfer	-do-	0.0002	0.0005
Greenhouse gases	CO_2	MT	3.9245	7.1311
	Total GWP (CO_2 eq)	MT	5.0636	8.9204
Energy use	Total	TJ	0.0578	0.0872
	Electricity	MKwh	0.0060	0.0068
	Coal	TJ	0.0177	0.0290
	Natural gas	TJ	0.0134	0.0241
	Motor Gasoline	TJ	0.0026	0.0040
Municipal Solid Waste	Total	MT	0.2271	0.2720
	Paper	MT	0.0849	0.1017
	Metals	MT	0.0176	0.0211
	Glass	MT	0.0124	0.0148
Water use	Intake (Total)	Bil gal	0	0
Safety	Total fatalities	Number	0	0
External costs	Median air pollution related	$ mil	0.0001	0.0002

6. CONCLUSIONS

This report summarizes the accomplishments of the project entitled, "*Integrated Economic Development and Environmental Protection Assessment for the Muskegon River Watershed.*" The ultimate goal of the project was to develop and demonstrate a flexible, user-friendly watershed information tool (WIT) for evaluating local development projects in the Muskegon River Watershed (MRW) in terms of both economic development and environmental protection goals.

The following four major components of the project have been completed over a three year period.

1. Construction of a detailed regional economic input-output model of the Muskegon River watershed.
2. Development of database of sector level environmental impact vectors, covering energy use, air emissions, water emissions, resource use, and summary indices.
3. Integration of these two to develop a user friendly internet software tool (WIT) for economic and environmental impact assessment of developmental projects in Muskegon River watershed.
4. A detailed case study to demonstrate the use of the tool.

These components were successfully completed despite facing several problems such as, unexpected retirement of one of the principal investigators, a significant mid-project reduction in funding from $116,290 to $79,000, a change in the software design from being a stand-alone PC based to an internet based software, and data problems arising from policy and practice changes at various government agencies. Various sections in this report provide detailed descriptions of the methods, processes for each of these components and the results. We have also made significant efforts in disseminating the information about the project among different stakeholders as discussed in Section 4.

The WIT however, has several potential limitations which have to be considered while applying the tool. These limitations and caveats arise both from the nature of input-output analysis and from the specific character of this method. WIT shares the fundamental limitations of input output analysis such as: linear approximation in technical coefficients, approximation of specific inputs by their corresponding input output sectors, static analysis and omission of capital service flows. Static analysis and linearity provide good approximations for relatively small changes, typical in regional analysis. Because capital services are consumed over a large number of individual units and do not result in actual material flows, the economic and environmental impacts from capital services are likely to be small.

Expressing all the environmental impact coefficients in terms of environmental burden/dollar value of sector output instead of familiar physical units such as tons, liters, service hours, and so on makes modeling simpler by avoiding the difficulty of incorporating multiple physical units and appropriate conversion factors in the model. Under constant price conditions, these impact coefficients can easily be translated to physical unit bases. However, geographical, temporal, margin and tax related variations in prices can introduce errors. Care should be taken to use producer prices of inputs and appropriate producer price indices to adjust for these variations.

Co-product allocation is a much debated topic in construction of national input output tables (Miller and Blair 1985). In the construction of US IO tables, commodity technology assumption is used in estimating technical coefficients for co-products (refer to USDOC 1994 for more details). WIT allocates environmental burdens on the basis of market value. Other suggested bases of allocation include mass, dry mass, energy content, incremental processing energy, and heat of reaction (SETAC 1993). For some specific projects, one of these allocation methods might be more appealing than other methods.

In deriving the regional input output tables, the national technical coefficient matrix is considered valid for all local, national and imported production. This may introduce errors in analyses, if technologies differ significantly. As discussed earlier in Section 3, because data from many different sources and time periods have been collected, normalized, aggregated and averaged to arrive at sector level environmental indices, there are significant uncertainties in these estimates.

Despite these limitations, WIT is a flexible and powerful tool that can provide quick, good, first approximations in estimating economic and environmental impacts of local development initiatives. It is best used as an initial screening device for choosing among alternatives, and for scoping and prioritizing further data collection and planning for selected projects. While the WIT does not provide all the information necessary for decisions, it can be a valuable tool in enabling informed decisions. We sincerely hope that the tool will be widely used and enable informed decisions by local policy makers, planners, and citizens in choosing among alternative local development initiatives.

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APPENDIX: COMPUTER SCREEN PRINTS OF THE WEBSITE AND MODEL INPUTS AND OUPUTS

Figure A1: Home Page

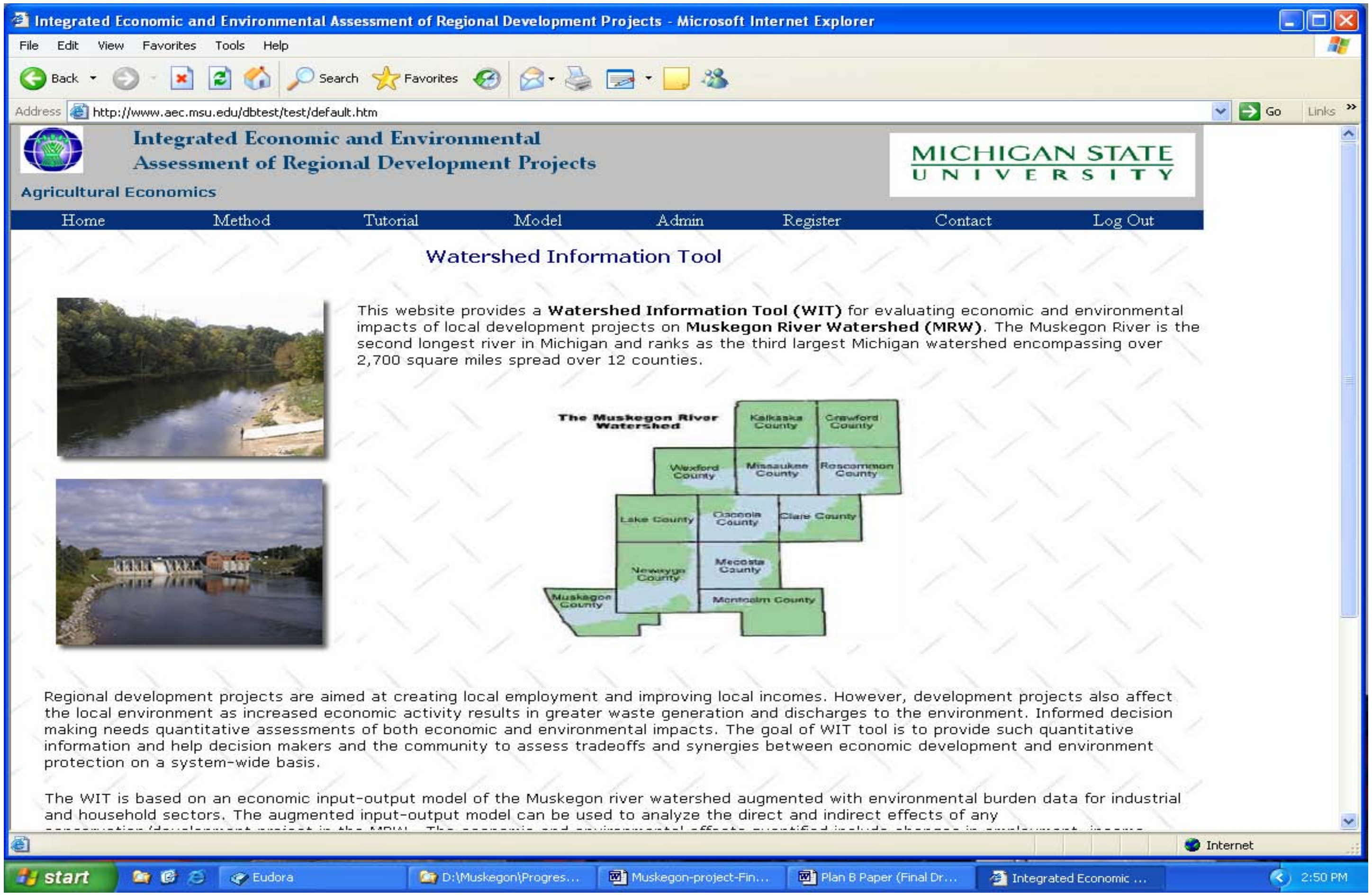
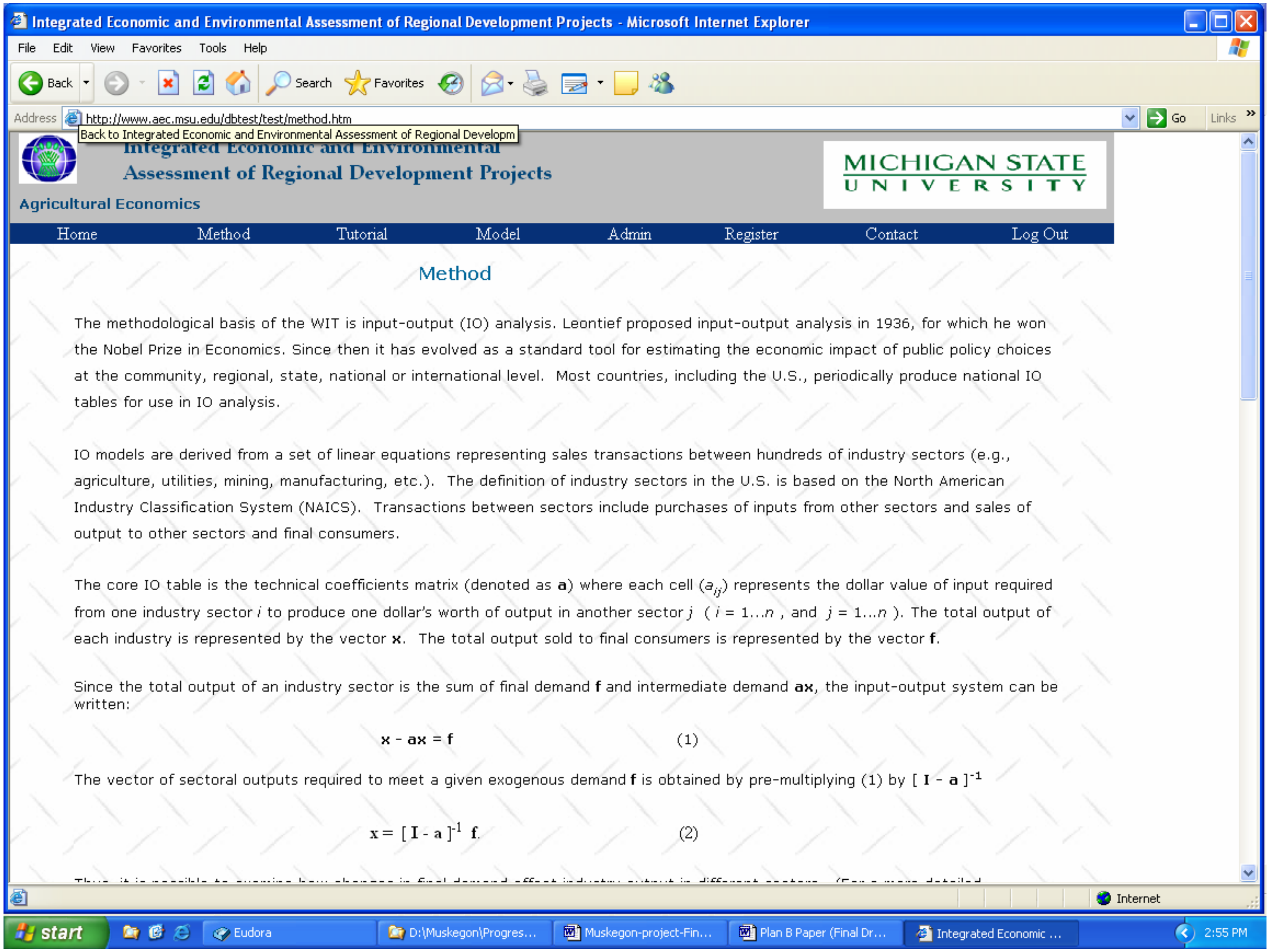


Figure A2: Methods Page 1.



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Method

The methodological basis of the WIT is input-output (IO) analysis. Leontief proposed input-output analysis in 1936, for which he won the Nobel Prize in Economics. Since then it has evolved as a standard tool for estimating the economic impact of public policy choices at the community, regional, state, national or international level. Most countries, including the U.S., periodically produce national IO tables for use in IO analysis.

IO models are derived from a set of linear equations representing sales transactions between hundreds of industry sectors (e.g., agriculture, utilities, mining, manufacturing, etc.). The definition of industry sectors in the U.S. is based on the North American Industry Classification System (NAICS). Transactions between sectors include purchases of inputs from other sectors and sales of output to other sectors and final consumers.

The core IO table is the technical coefficients matrix (denoted as **a**) where each cell (a_{ij}) represents the dollar value of input required from one industry sector i to produce one dollar's worth of output in another sector j (i = 1...n , and j = 1...n). The total output of each industry is represented by the vector **x**. The total output sold to final consumers is represented by the vector **f**.

Since the total output of an industry sector is the sum of final demand **f** and intermediate demand **ax**, the input-output system can be written:

$$\mathbf{x} - \mathbf{ax} = \mathbf{f} \qquad (1)$$

The vector of sectoral outputs required to meet a given exogenous demand **f** is obtained by pre-multiplying (1) by $[\,\mathbf{I} - \mathbf{a}\,]^{-1}$

$$\mathbf{x} = [\,\mathbf{I} - \mathbf{a}\,]^{-1}\,\mathbf{f}. \qquad (2)$$

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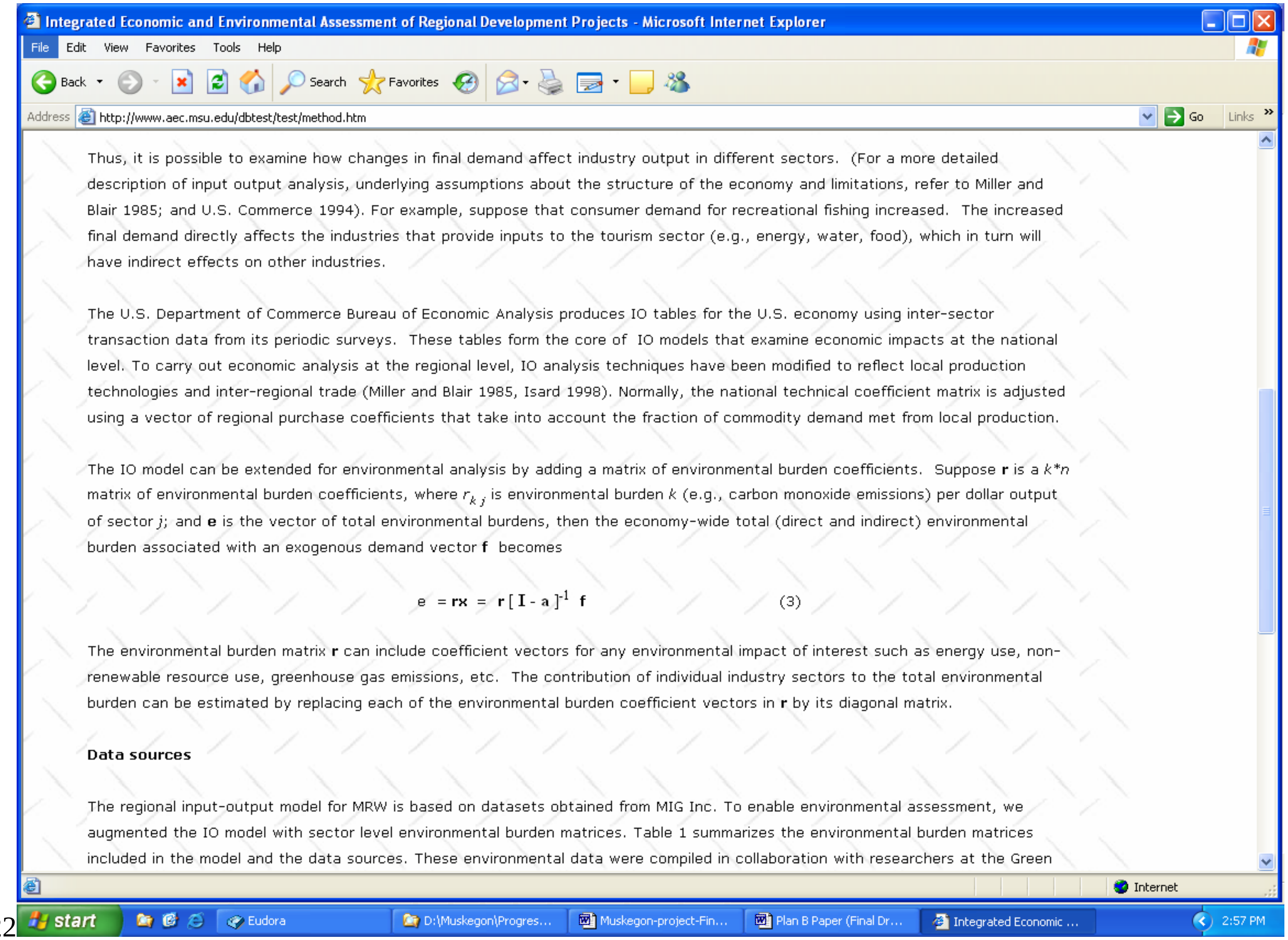
Figure A3: Methods Page 2



Thus, it is possible to examine how changes in final demand affect industry output in different sectors. (For a more detailed description of input output analysis, underlying assumptions about the structure of the economy and limitations, refer to Miller and Blair 1985; and U.S. Commerce 1994). For example, suppose that consumer demand for recreational fishing increased. The increased final demand directly affects the industries that provide inputs to the tourism sector (e.g., energy, water, food), which in turn will have indirect effects on other industries.

The U.S. Department of Commerce Bureau of Economic Analysis produces IO tables for the U.S. economy using inter-sector transaction data from its periodic surveys. These tables form the core of IO models that examine economic impacts at the national level. To carry out economic analysis at the regional level, IO analysis techniques have been modified to reflect local production technologies and inter-regional trade (Miller and Blair 1985, Isard 1998). Normally, the national technical coefficient matrix is adjusted using a vector of regional purchase coefficients that take into account the fraction of commodity demand met from local production.

The IO model can be extended for environmental analysis by adding a matrix of environmental burden coefficients. Suppose **r** is a $k*n$ matrix of environmental burden coefficients, where $r_{k\,j}$ is environmental burden k (e.g., carbon monoxide emissions) per dollar output of sector j; and **e** is the vector of total environmental burdens, then the economy-wide total (direct and indirect) environmental burden associated with an exogenous demand vector **f** becomes

$$e = \mathbf{rx} = \mathbf{r}[\mathrm{I} - \mathrm{a}]^{-1}\ \mathbf{f} \qquad (3)$$

The environmental burden matrix **r** can include coefficient vectors for any environmental impact of interest such as energy use, non-renewable resource use, greenhouse gas emissions, etc. The contribution of individual industry sectors to the total environmental burden can be estimated by replacing each of the environmental burden coefficient vectors in **r** by its diagonal matrix.

Data sources

The regional input-output model for MRW is based on datasets obtained from MIG Inc. To enable environmental assessment, we augmented the IO model with sector level environmental burden matrices. Table 1 summarizes the environmental burden matrices included in the model and the data sources. These environmental data were compiled in collaboration with researchers at the Green

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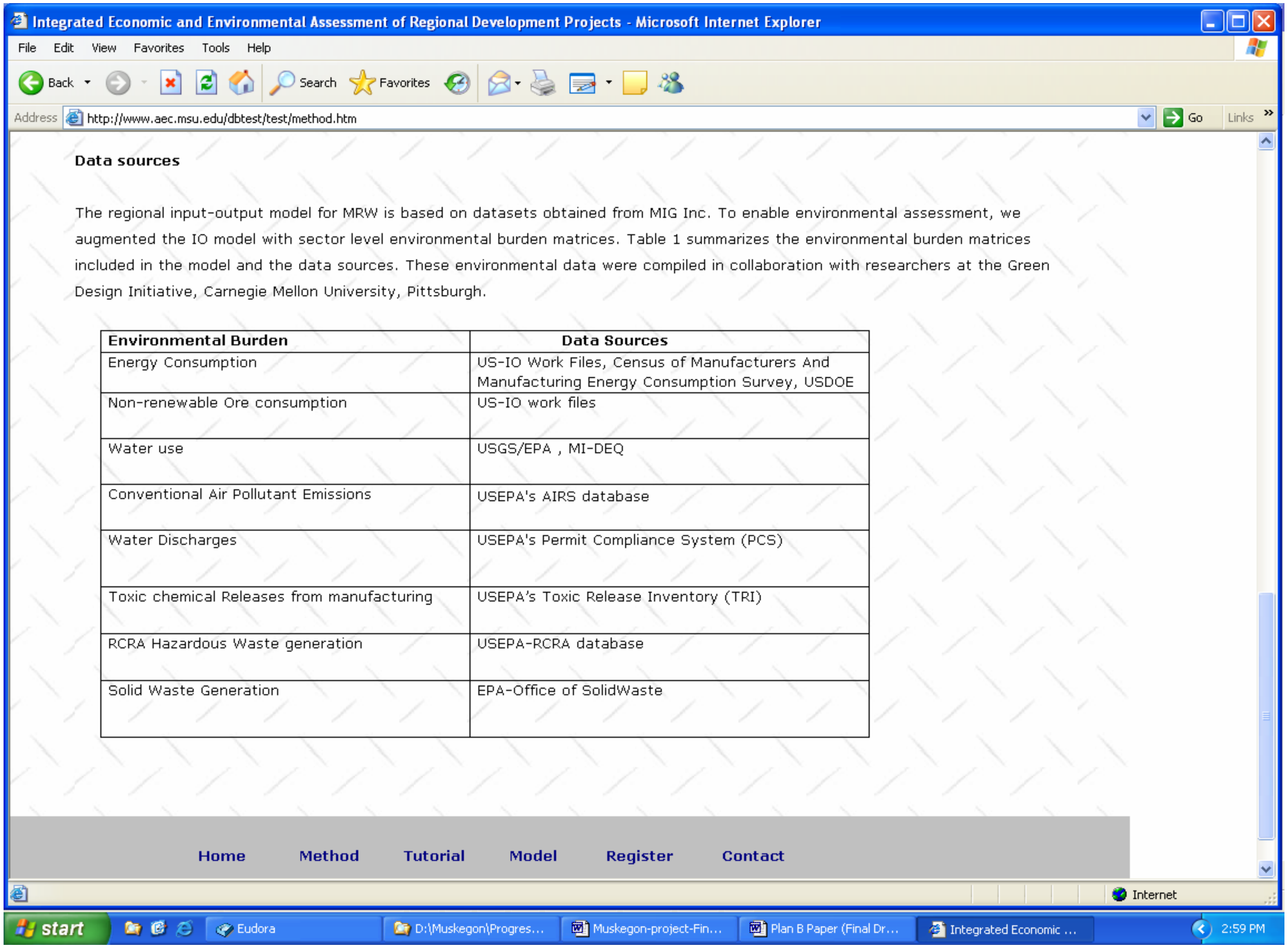
Figure A4: Methods Page 3



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http://www.aec.msu.edu/dbtest/test/method.htm

Data sources

The regional input-output model for MRW is based on datasets obtained from MIG Inc. To enable environmental assessment, we augmented the IO model with sector level environmental burden matrices. Table 1 summarizes the environmental burden matrices included in the model and the data sources. These environmental data were compiled in collaboration with researchers at the Green Design Initiative, Carnegie Mellon University, Pittsburgh.

Environmental Burden	Data Sources
Energy Consumption	US-IO Work Files, Census of Manufacturers And Manufacturing Energy Consumption Survey, USDOE
Non-renewable Ore consumption	US-IO work files
Water use	USGS/EPA , MI-DEQ
Conventional Air Pollutant Emissions	USEPA's AIRS database
Water Discharges	USEPA's Permit Compliance System (PCS)
Toxic chemical Releases from manufacturing	USEPA's Toxic Release Inventory (TRI)
RCRA Hazardous Waste generation	USEPA-RCRA database
Solid Waste Generation	EPA-Office of SolidWaste

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Figure A5 : Online Tutorial (Page 1 only)

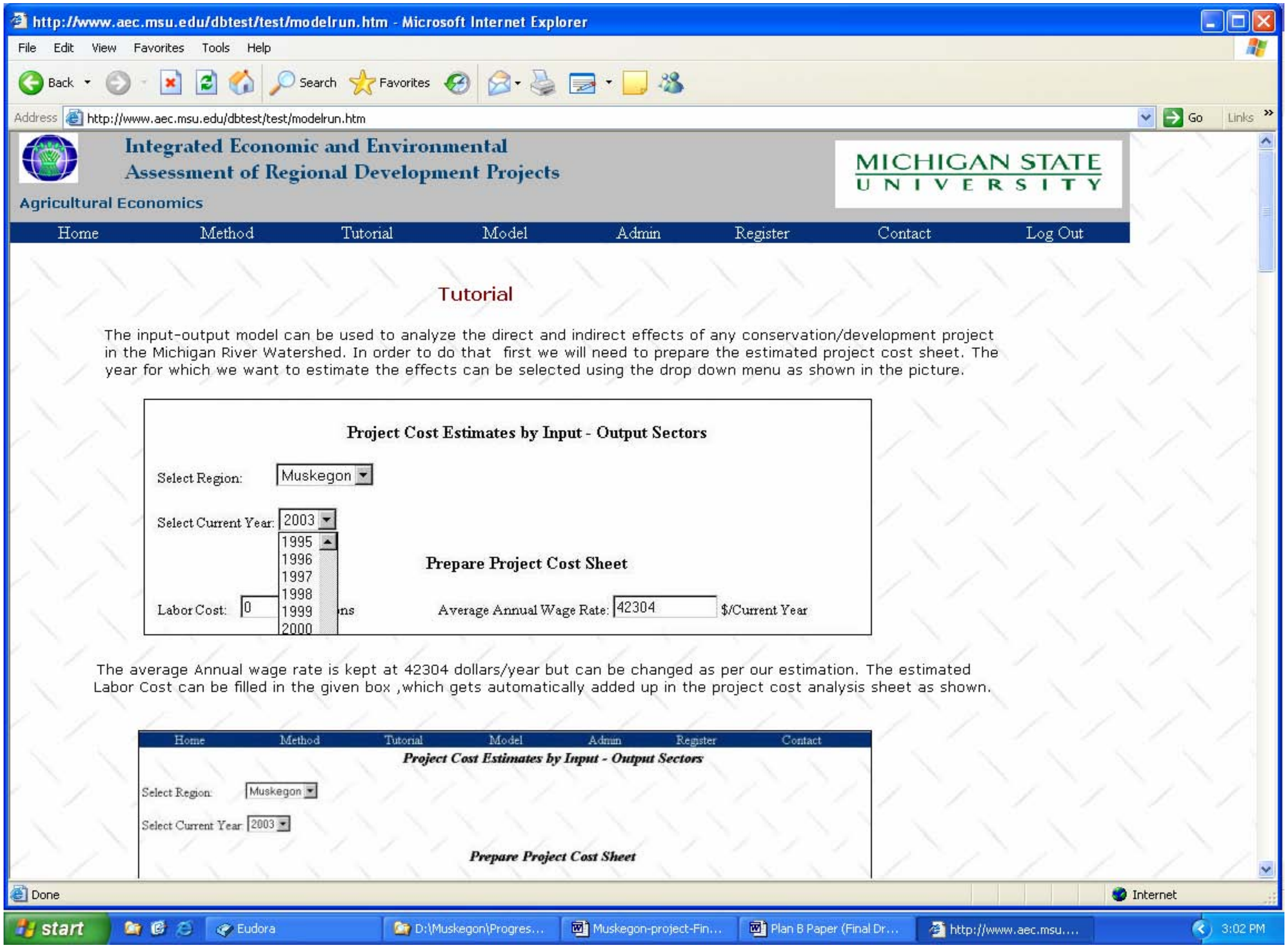


Figure A6: Blank Model Input Page 1

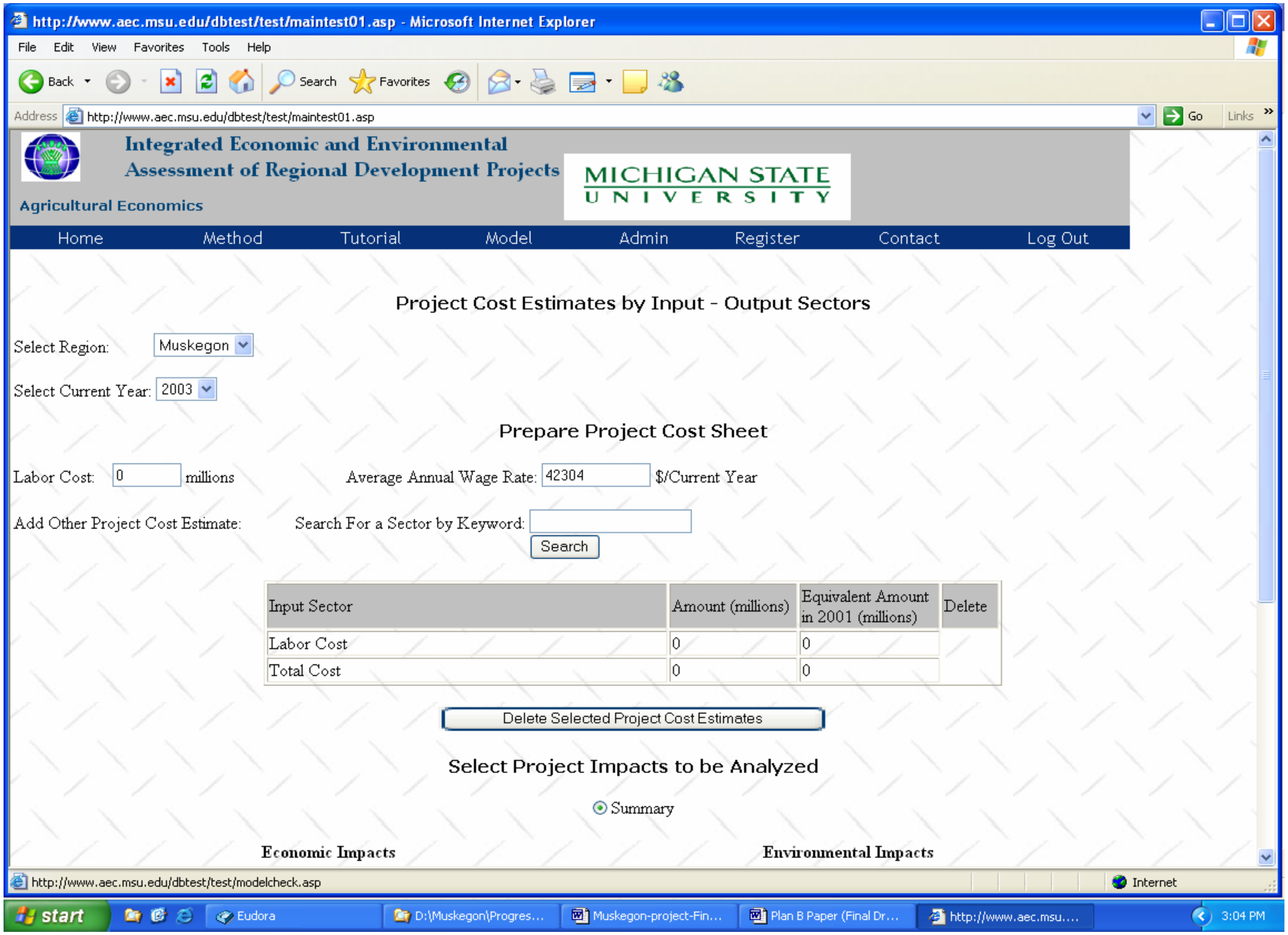


Figure A7: Blank Model Input Sheet (page 2: Showing impact selection radio buttons)

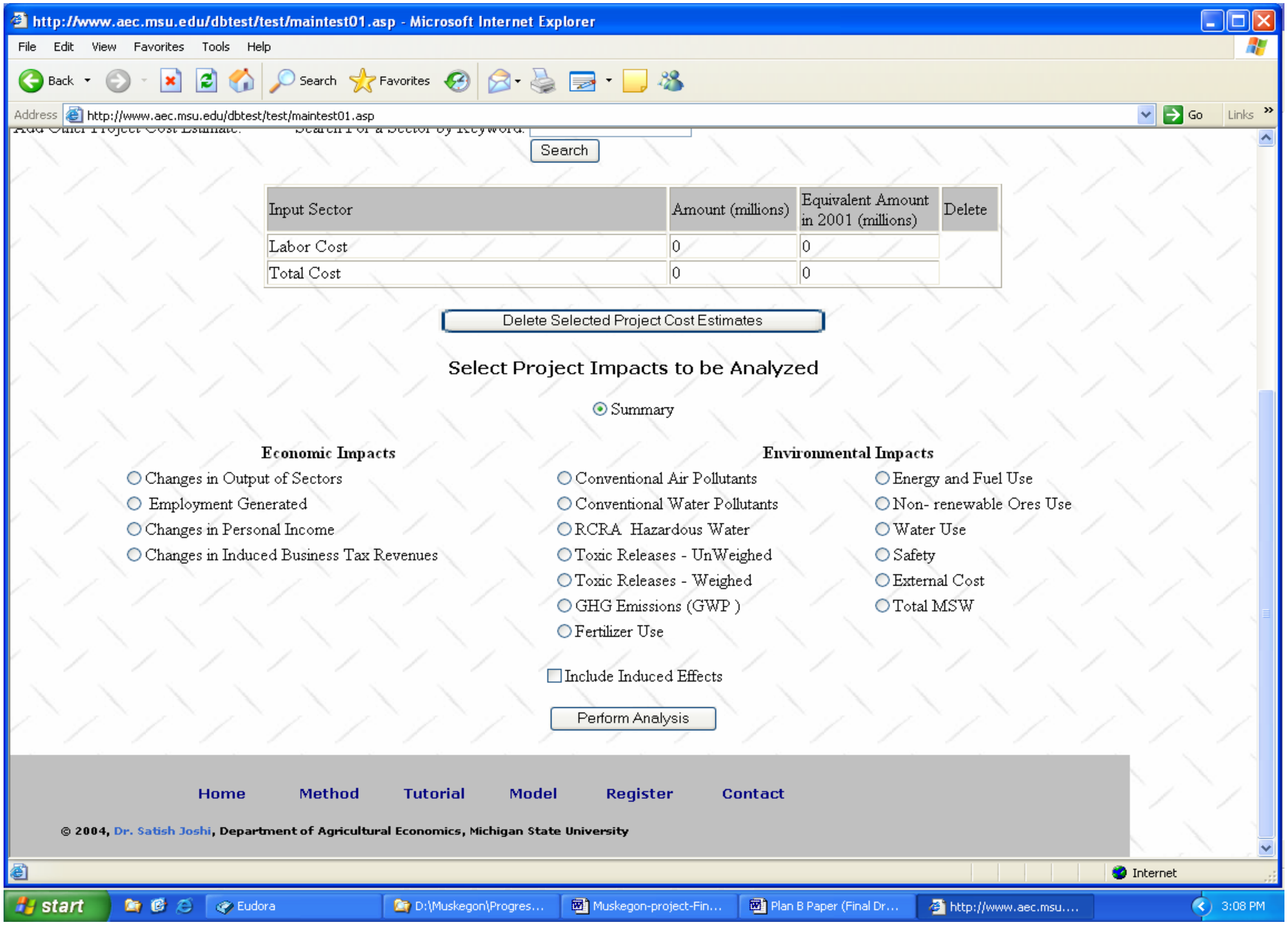


Figure A8: Model input sheet with Marion restoration project costs filled in (Page 1)

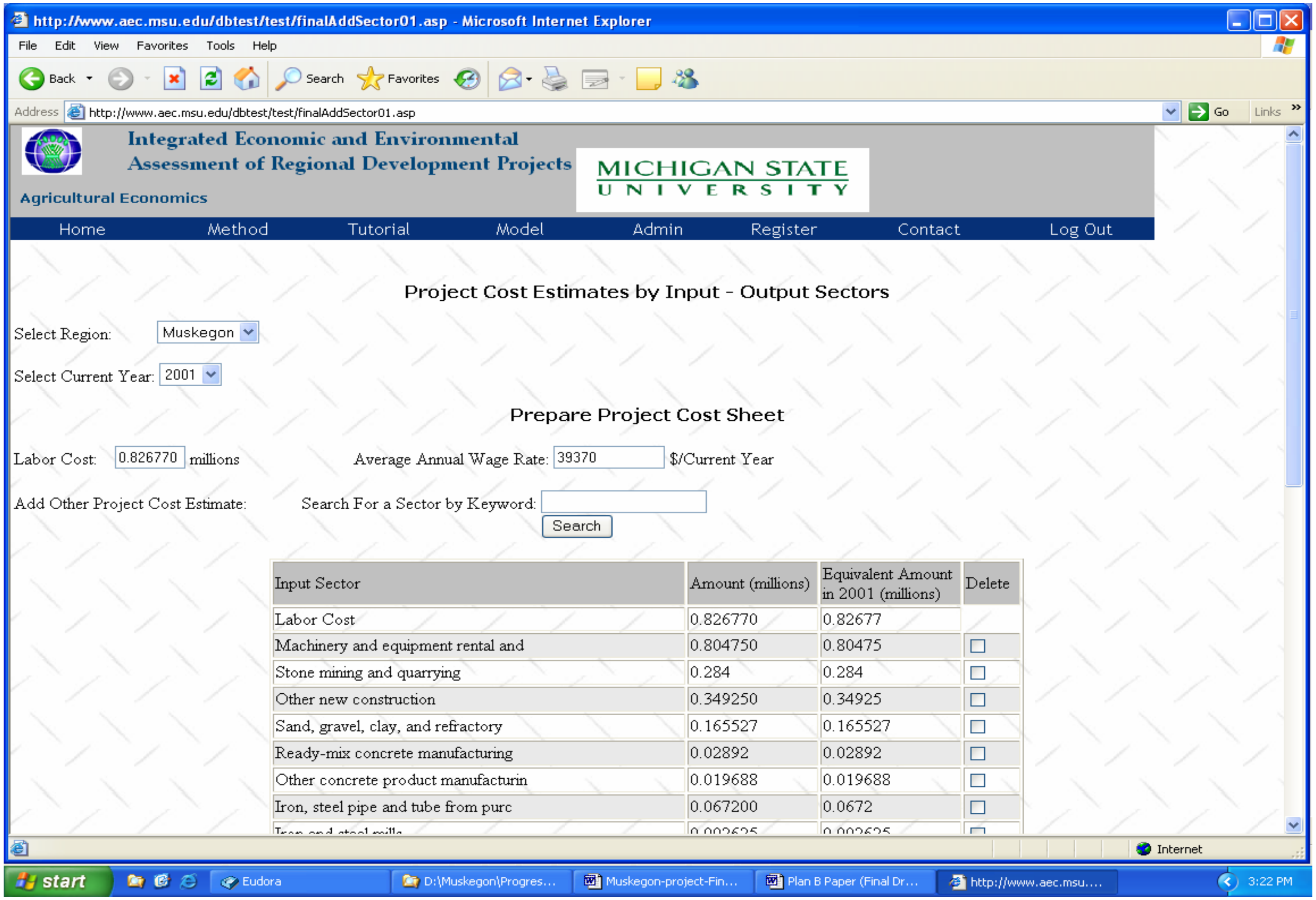
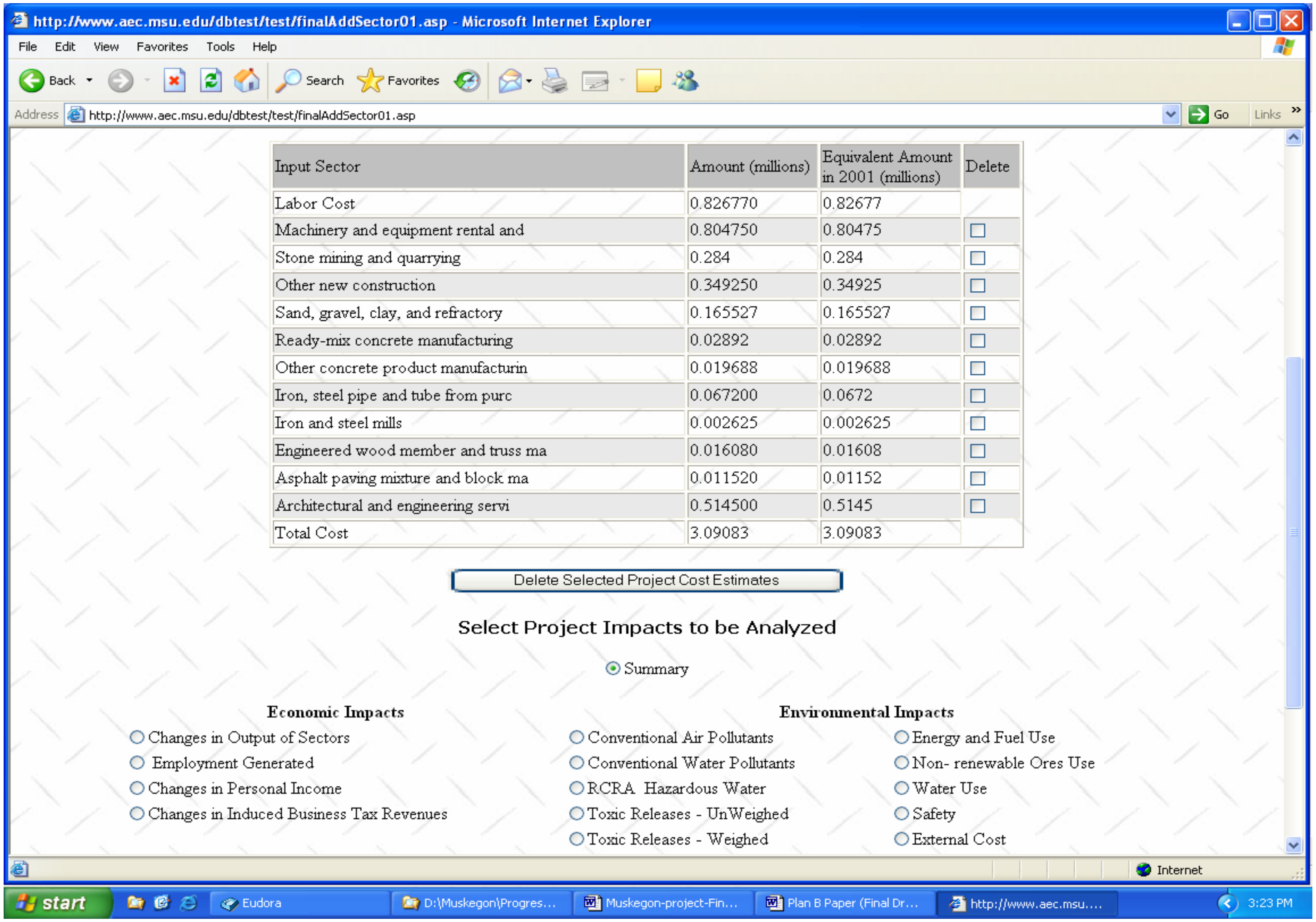


Figure A9: Model input sheet with Marion restoration project costs filled in (Page 2)



http://www.aec.msu.edu/dbtest/test/finalAddSector01.asp - Microsoft Internet Explorer

Input Sector	Amount (millions)	Equivalent Amount in 2001 (millions)	Delete
Labor Cost	0.826770	0.82677	
Machinery and equipment rental and	0.804750	0.80475	☐
Stone mining and quarrying	0.284	0.284	☐
Other new construction	0.349250	0.34925	☐
Sand, gravel, clay, and refractory	0.165527	0.165527	☐
Ready-mix concrete manufacturing	0.02892	0.02892	☐
Other concrete product manufacturin	0.019688	0.019688	☐
Iron, steel pipe and tube from purc	0.067200	0.0672	☐
Iron and steel mills	0.002625	0.002625	☐
Engineered wood member and truss ma	0.016080	0.01608	☐
Asphalt paving mixture and block ma	0.011520	0.01152	☐
Architectural and engineering servi	0.514500	0.5145	☐
Total Cost	3.09083	3.09083	

Delete Selected Project Cost Estimates

Select Project Impacts to be Analyzed

◉ Summary

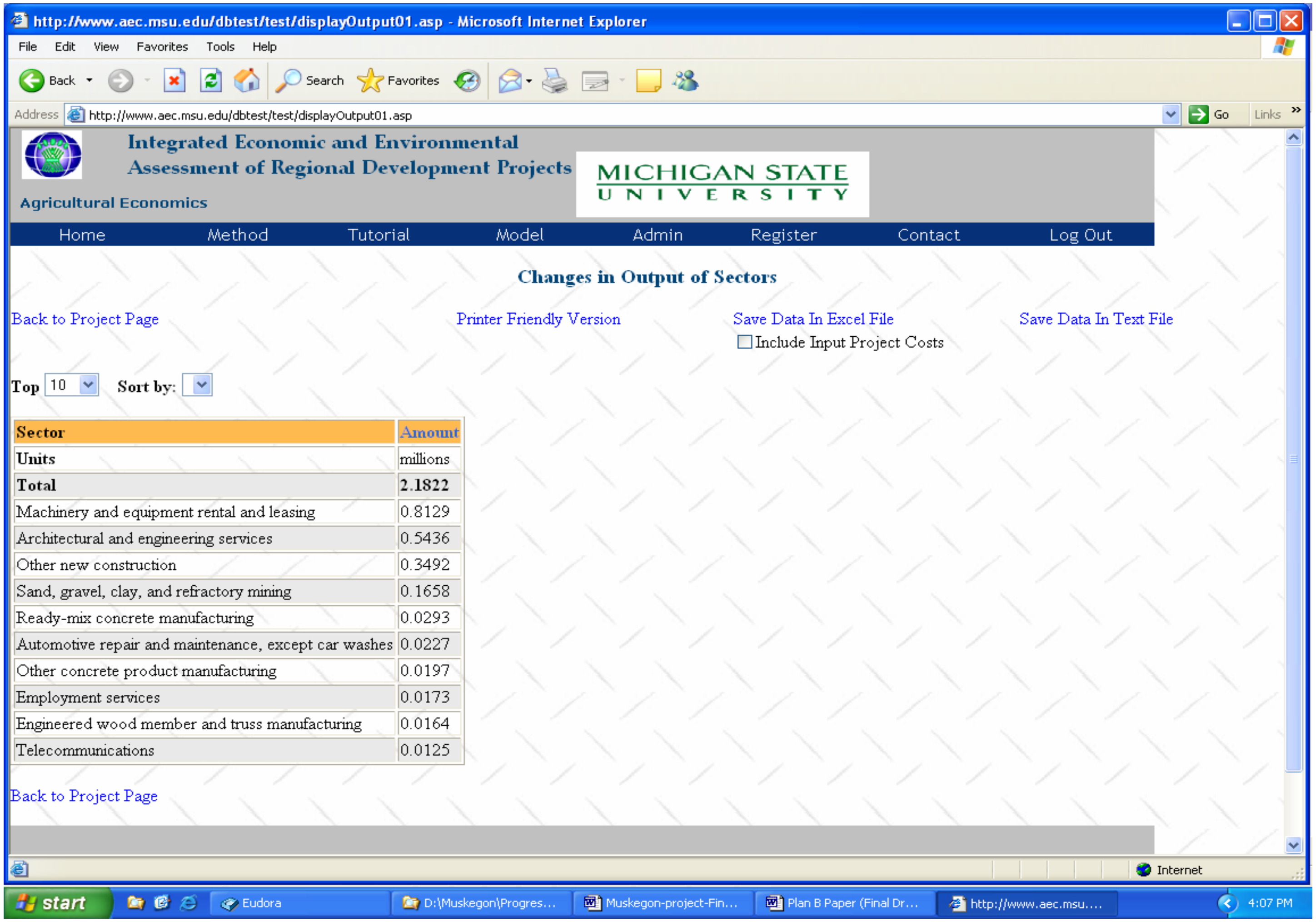
Economic Impacts

○ Changes in Output of Sectors
○ Employment Generated
○ Changes in Personal Income
○ Changes in Induced Business Tax Revenues

Environmental Impacts

○ Conventional Air Pollutants
○ Conventional Water Pollutants
○ RCRA Hazardous Water
○ Toxic Releases - UnWeighed
○ Toxic Releases - Weighed
○ Energy and Fuel Use
○ Non- renewable Ores Use
○ Water Use
○ Safety
○ External Cost

Figure A9: Model output of economic impacts (Sector output changes) of the Marion restoration project



Sector	Amount
Units	millions
Total	**2.1822**
Machinery and equipment rental and leasing	0.8129
Architectural and engineering services	0.5436
Other new construction	0.3492
Sand, gravel, clay, and refractory mining	0.1658
Ready-mix concrete manufacturing	0.0293
Automotive repair and maintenance, except car washes	0.0227
Other concrete product manufacturing	0.0197
Employment services	0.0173
Engineered wood member and truss manufacturing	0.0164
Telecommunications	0.0125

Figure A10: Model Output: Employment impacts of the Marion restoration project

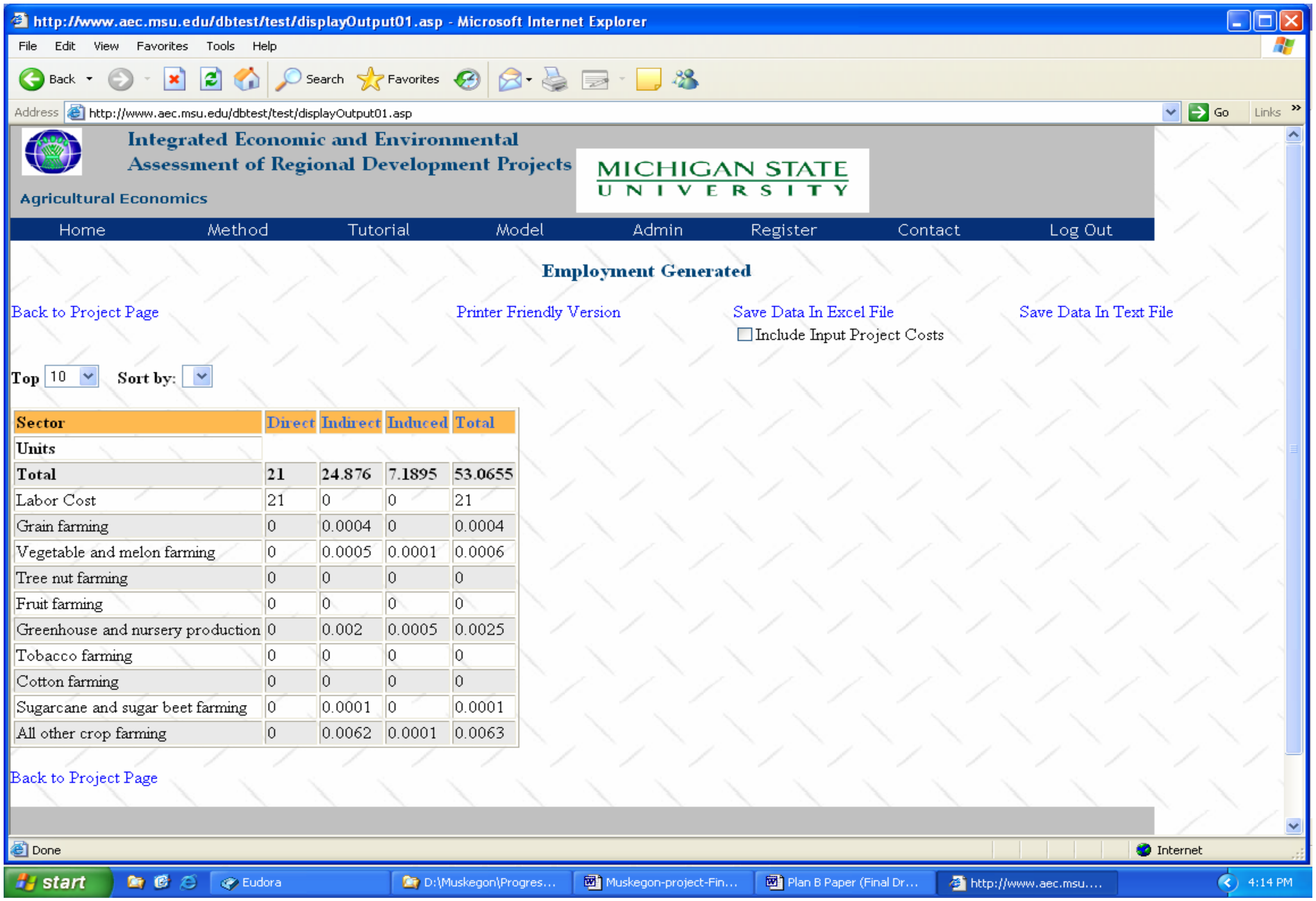
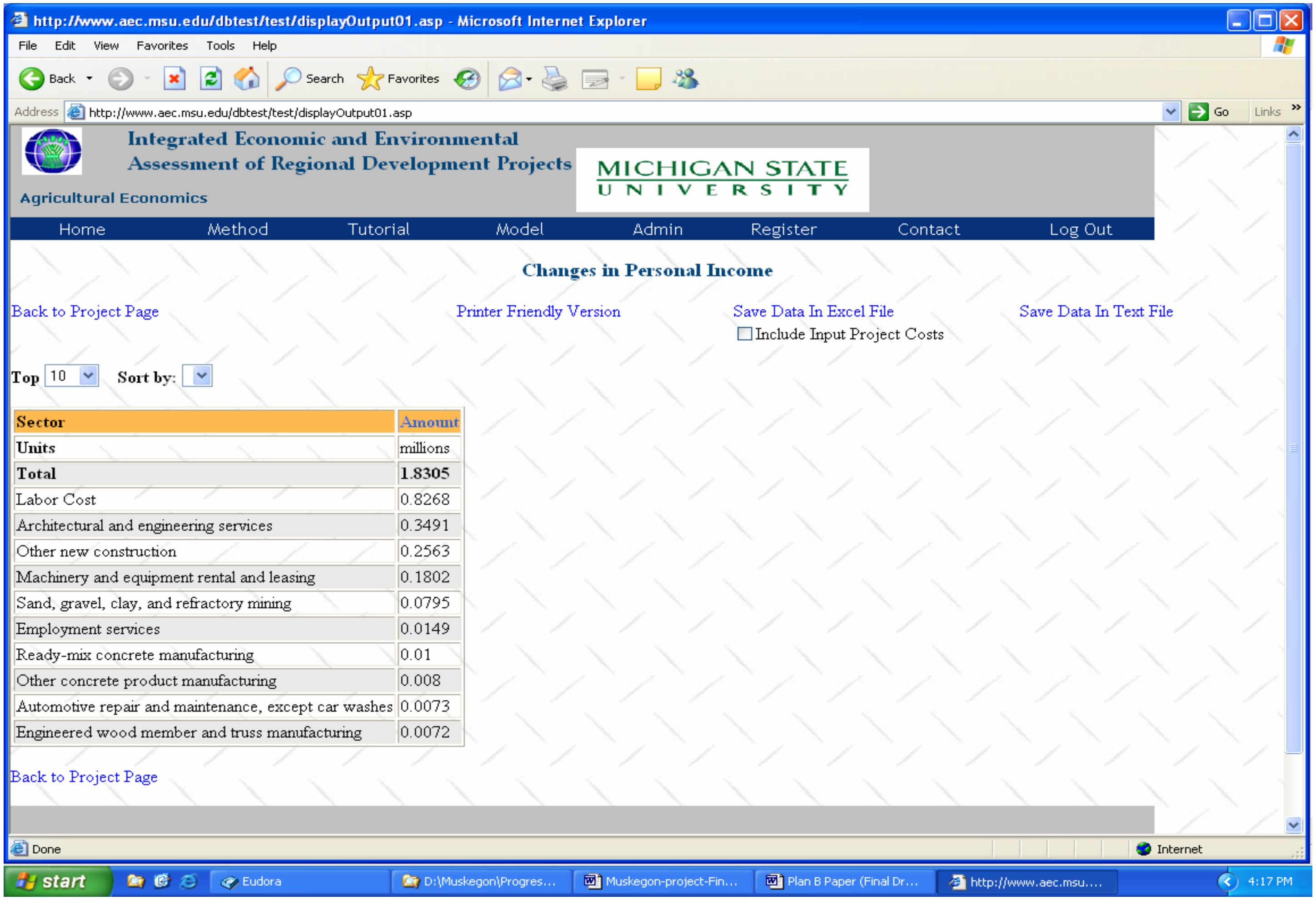
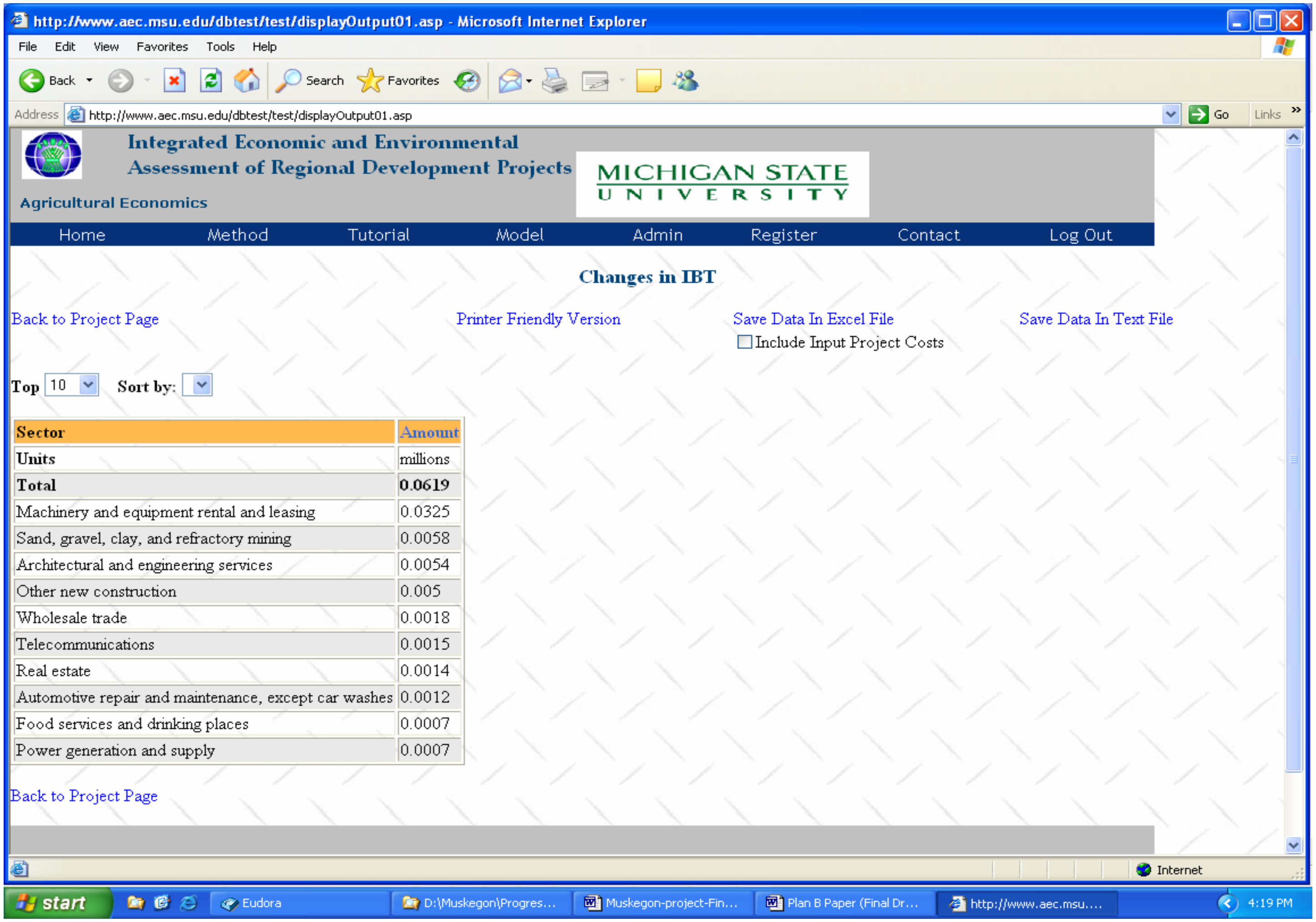


Figure A11: Model Output: Personal income impacts of the Marion restoration project



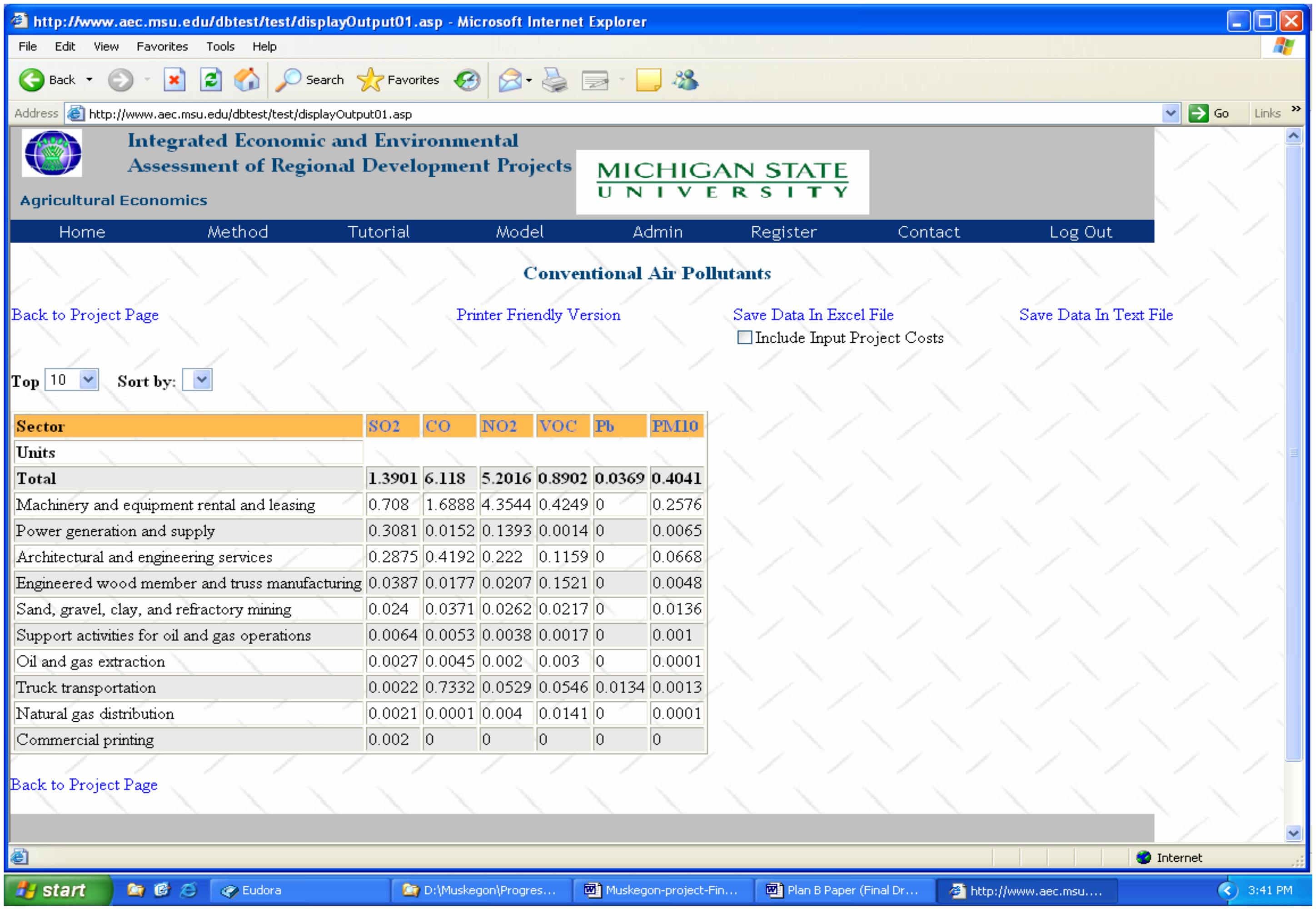
Sector	Amount
Units	millions
Total	**1.8305**
Labor Cost	0.8268
Architectural and engineering services	0.3491
Other new construction	0.2563
Machinery and equipment rental and leasing	0.1802
Sand, gravel, clay, and refractory mining	0.0795
Employment services	0.0149
Ready-mix concrete manufacturing	0.01
Other concrete product manufacturing	0.008
Automotive repair and maintenance, except car washes	0.0073
Engineered wood member and truss manufacturing	0.0072

Figure A12: Model output: Indirect business tax impacts of the Marion restoration project



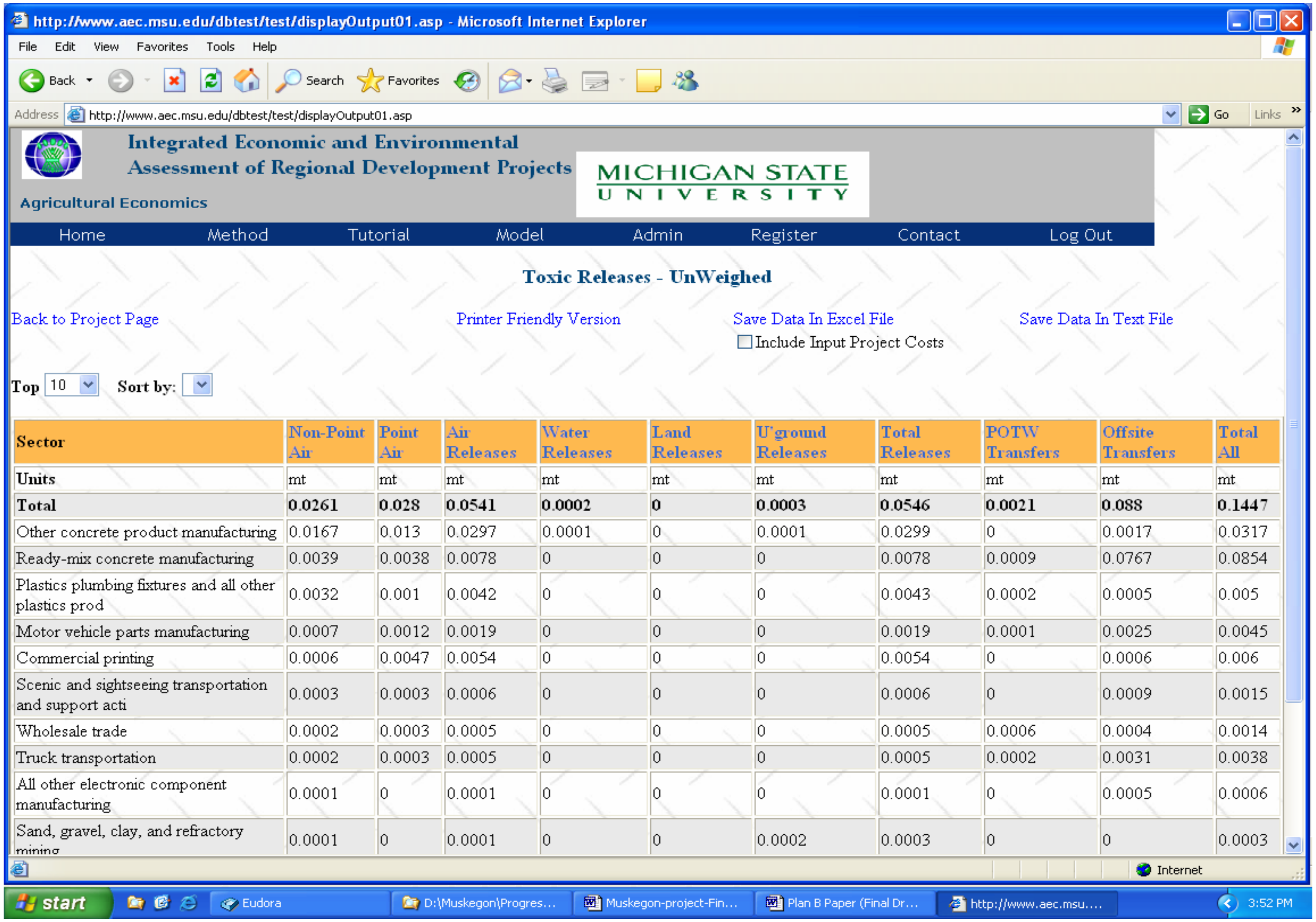
Sector	Amount
Units	millions
Total	0.0619
Machinery and equipment rental and leasing	0.0325
Sand, gravel, clay, and refractory mining	0.0058
Architectural and engineering services	0.0054
Other new construction	0.005
Wholesale trade	0.0018
Telecommunications	0.0015
Real estate	0.0014
Automotive repair and maintenance, except car washes	0.0012
Food services and drinking places	0.0007
Power generation and supply	0.0007

Figure A13 : Model Output : Air Pollution impacts of the Marion restoration project



Sector	SO2	CO	NO2	VOC	Pb	PM10
Units						
Total	**1.3901**	**6.118**	**5.2016**	**0.8902**	**0.0369**	**0.4041**
Machinery and equipment rental and leasing	0.708	1.6888	4.3544	0.4249	0	0.2576
Power generation and supply	0.3081	0.0152	0.1393	0.0014	0	0.0065
Architectural and engineering services	0.2875	0.4192	0.222	0.1159	0	0.0668
Engineered wood member and truss manufacturing	0.0387	0.0177	0.0207	0.1521	0	0.0048
Sand, gravel, clay, and refractory mining	0.024	0.0371	0.0262	0.0217	0	0.0136
Support activities for oil and gas operations	0.0064	0.0053	0.0038	0.0017	0	0.001
Oil and gas extraction	0.0027	0.0045	0.002	0.003	0	0.0001
Truck transportation	0.0022	0.7332	0.0529	0.0546	0.0134	0.0013
Natural gas distribution	0.0021	0.0001	0.004	0.0141	0	0.0001
Commercial printing	0.002	0	0	0	0	0

Figure A14: Toxic Releases (unweighted) impact of the Marion Project



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Toxic Releases - UnWeighed

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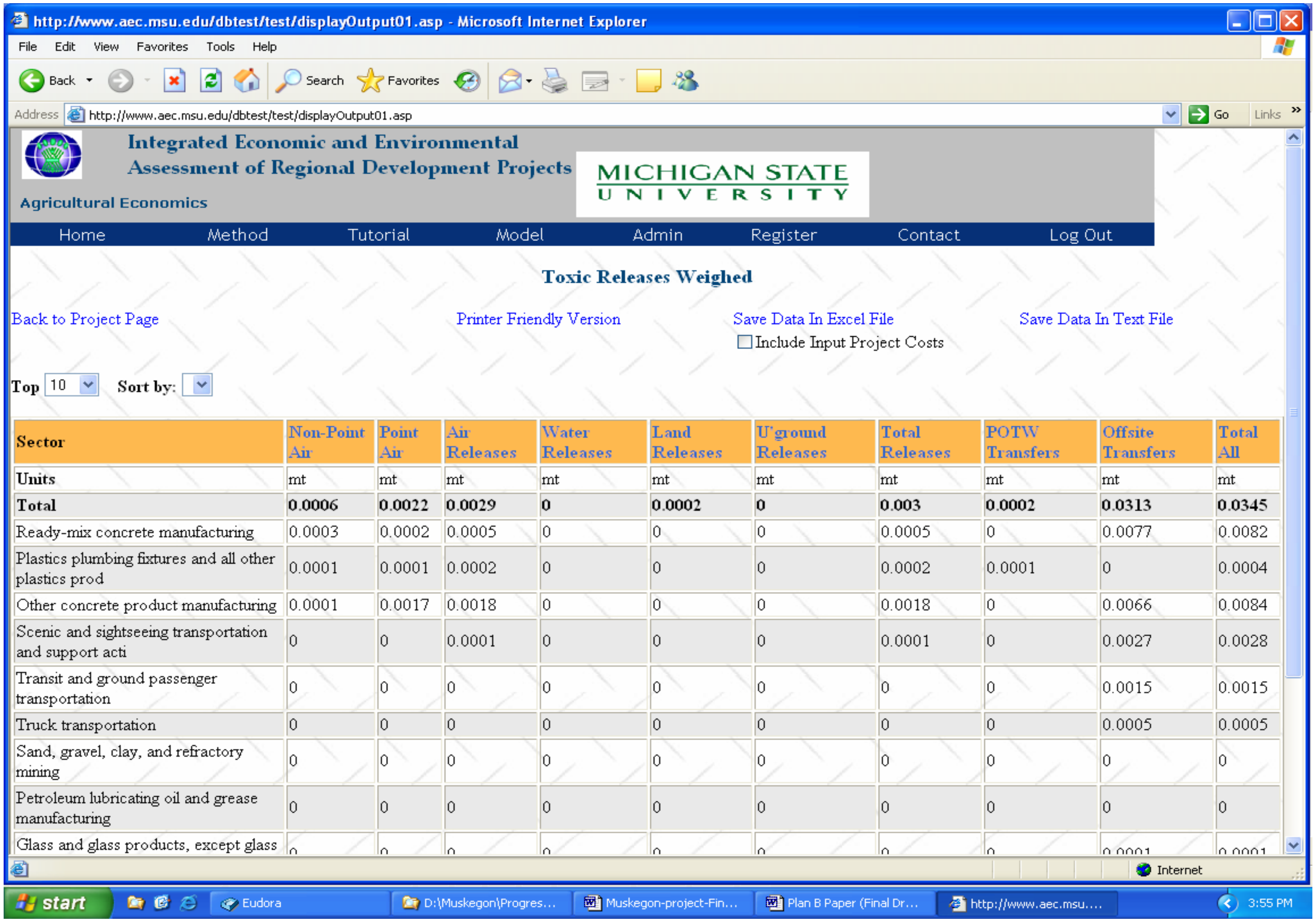
Include Input Project Costs

Top 10 Sort by:

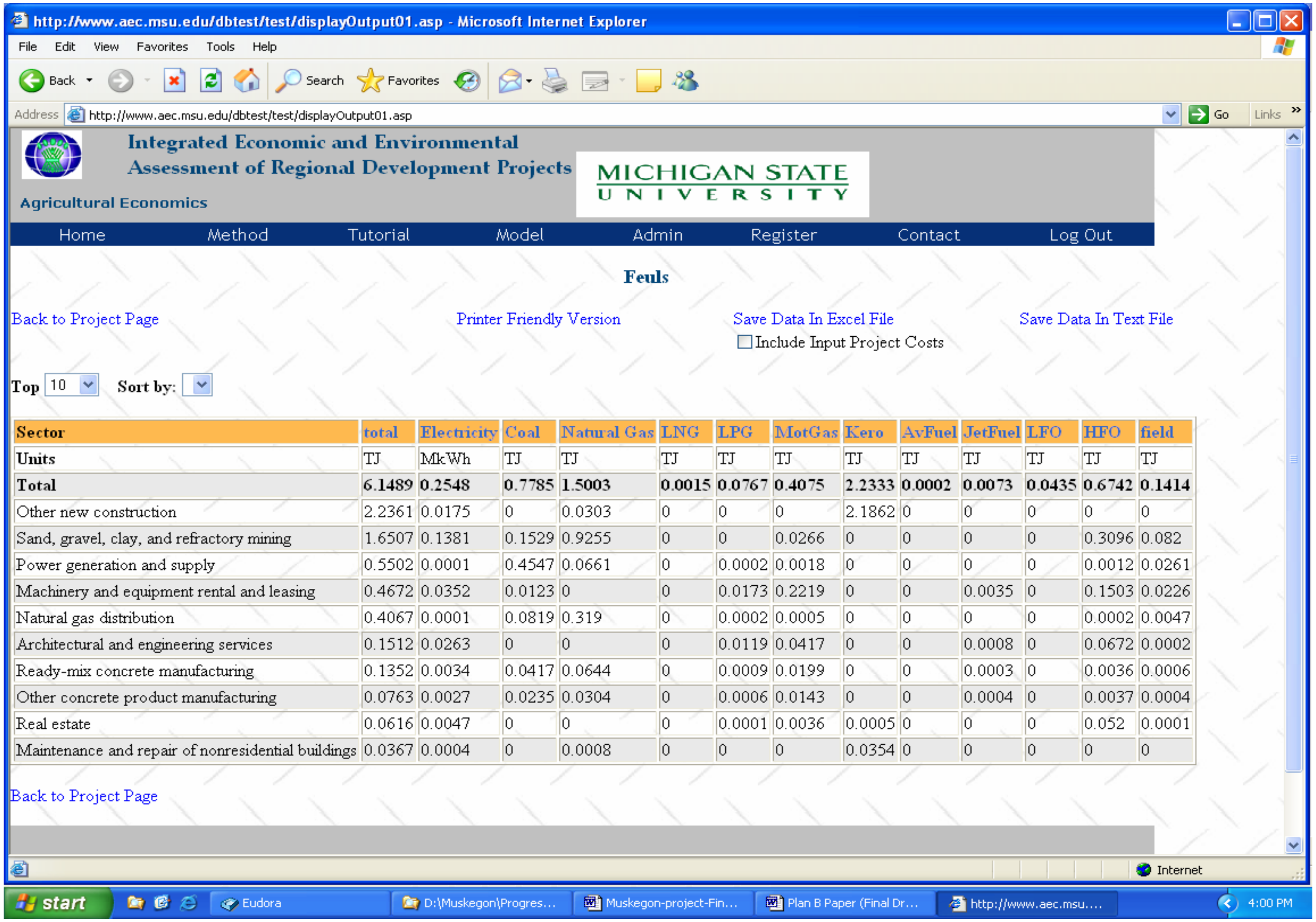
Sector	Non-Point Air	Point Air	Air Releases	Water Releases	Land Releases	U'ground Releases	Total Releases	POTW Transfers	Offsite Transfers	Total All
Units	mt	mt	mt	mt	mt	mt	mt	mt	mt	mt
Total	**0.0261**	**0.028**	**0.0541**	**0.0002**	**0**	**0.0003**	**0.0546**	**0.0021**	**0.088**	**0.1447**
Other concrete product manufacturing	0.0167	0.013	0.0297	0.0001	0	0.0001	0.0299	0	0.0017	0.0317
Ready-mix concrete manufacturing	0.0039	0.0038	0.0078	0	0	0	0.0078	0.0009	0.0767	0.0854
Plastics plumbing fixtures and all other plastics prod	0.0032	0.001	0.0042	0	0	0	0.0043	0.0002	0.0005	0.005
Motor vehicle parts manufacturing	0.0007	0.0012	0.0019	0	0	0	0.0019	0.0001	0.0025	0.0045
Commercial printing	0.0006	0.0047	0.0054	0	0	0	0.0054	0	0.0006	0.006
Scenic and sightseeing transportation and support acti	0.0003	0.0003	0.0006	0	0	0	0.0006	0	0.0009	0.0015
Wholesale trade	0.0002	0.0003	0.0005	0	0	0	0.0005	0.0006	0.0004	0.0014
Truck transportation	0.0002	0.0003	0.0005	0	0	0	0.0005	0.0002	0.0031	0.0038
All other electronic component manufacturing	0.0001	0	0.0001	0	0	0	0.0001	0	0.0005	0.0006
Sand, gravel, clay, and refractory mining	0.0001	0	0.0001	0	0	0.0002	0.0003	0	0	0.0003

Figure A15: Toxic Releases (weighted CMU-ET) impact of the Marion Project



Sector	Non-Point Air	Point Air	Air Releases	Water Releases	Land Releases	U'ground Releases	Total Releases	POTW Transfers	Offsite Transfers	Total All
Units	mt	mt	mt	mt	mt	mt	mt	mt	mt	mt
Total	**0.0006**	**0.0022**	**0.0029**	**0**	**0.0002**	**0**	**0.003**	**0.0002**	**0.0313**	**0.0345**
Ready-mix concrete manufacturing	0.0003	0.0002	0.0005	0	0	0	0.0005	0	0.0077	0.0082
Plastics plumbing fixtures and all other plastics prod	0.0001	0.0001	0.0002	0	0	0	0.0002	0.0001	0	0.0004
Other concrete product manufacturing	0.0001	0.0017	0.0018	0	0	0	0.0018	0	0.0066	0.0084
Scenic and sightseeing transportation and support acti	0	0	0.0001	0	0	0	0.0001	0	0.0027	0.0028
Transit and ground passenger transportation	0	0	0	0	0	0	0	0	0.0015	0.0015
Truck transportation	0	0	0	0	0	0	0	0	0.0005	0.0005
Sand, gravel, clay, and refractory mining	0	0	0	0	0	0	0	0	0	0
Petroleum lubricating oil and grease manufacturing	0	0	0	0	0	0	0	0	0	0
Glass and glass products, except glass	0	0	0	0	0	0	0	0	0.0001	0.0001

Figure A16: Model output: Energy and Fuel Use from the Marion restoration project



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Include Input Project Costs

Top 10 Sort by:

Sector	total	Electricity	Coal	Natural Gas	LNG	LPG	MotGas	Kero	AvFuel	JetFuel	LFO	HFO	field
Units	TJ	MkWh	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ
Total	**6.1489**	**0.2548**	**0.7785**	**1.5003**	**0.0015**	**0.0767**	**0.4075**	**2.2333**	**0.0002**	**0.0073**	**0.0435**	**0.6742**	**0.1414**
Other new construction	2.2361	0.0175	0	0.0303	0	0	0	2.1862	0	0	0	0	0
Sand, gravel, clay, and refractory mining	1.6507	0.1381	0.1529	0.9255	0	0	0.0266	0	0	0	0	0.3096	0.082
Power generation and supply	0.5502	0.0001	0.4547	0.0661	0	0.0002	0.0018	0	0	0	0	0.0012	0.0261
Machinery and equipment rental and leasing	0.4672	0.0352	0.0123	0	0	0.0173	0.2219	0	0	0.0035	0	0.1503	0.0226
Natural gas distribution	0.4067	0.0001	0.0819	0.319	0	0.0002	0.0005	0	0	0	0	0.0002	0.0047
Architectural and engineering services	0.1512	0.0263	0	0	0	0.0119	0.0417	0	0	0.0008	0	0.0672	0.0002
Ready-mix concrete manufacturing	0.1352	0.0034	0.0417	0.0644	0	0.0009	0.0199	0	0	0.0003	0	0.0036	0.0006
Other concrete product manufacturing	0.0763	0.0027	0.0235	0.0304	0	0.0006	0.0143	0	0	0.0004	0	0.0037	0.0004
Real estate	0.0616	0.0047	0	0	0	0.0001	0.0036	0.0005	0	0	0	0.052	0.0001
Maintenance and repair of nonresidential buildings	0.0367	0.0004	0	0.0008	0	0	0	0.0354	0	0	0	0	0

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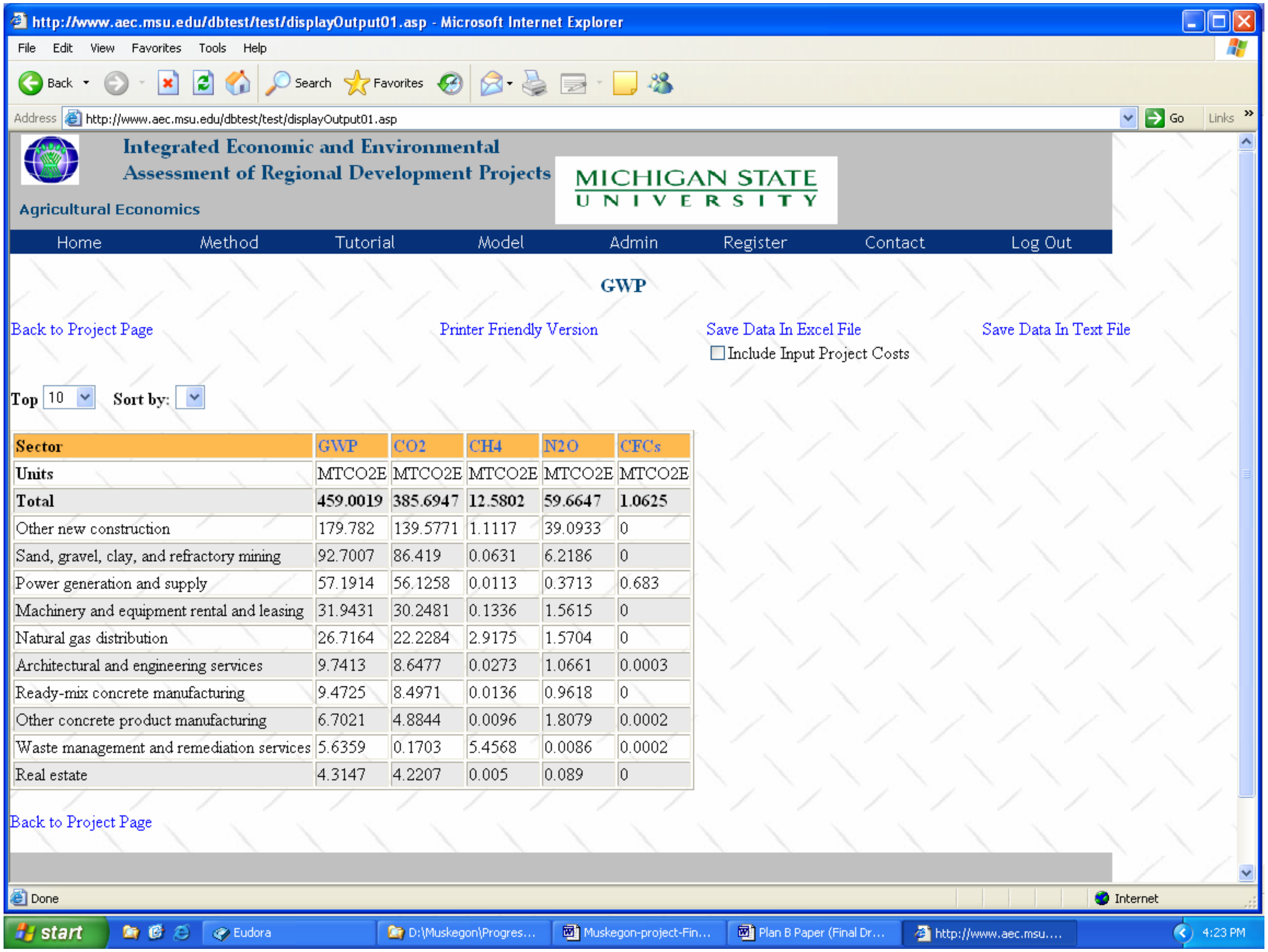
Figure A17: Model output: Greenhouse gas impacts from Marion Restoration Project



Sector	GWP	CO2	CH4	N2O	CFCs
Units	MTCO2E	MTCO2E	MTCO2E	MTCO2E	MTCO2E
Total	**459.0019**	**385.6947**	**12.5802**	**59.6647**	**1.0625**
Other new construction	179.782	139.5771	1.1117	39.0933	0
Sand, gravel, clay, and refractory mining	92.7007	86.419	0.0631	6.2186	0
Power generation and supply	57.1914	56.1258	0.0113	0.3713	0.683
Machinery and equipment rental and leasing	31.9431	30.2481	0.1336	1.5615	0
Natural gas distribution	26.7164	22.2284	2.9175	1.5704	0
Architectural and engineering services	9.7413	8.6477	0.0273	1.0661	0.0003
Ready-mix concrete manufacturing	9.4725	8.4971	0.0136	0.9618	0
Other concrete product manufacturing	6.7021	4.8844	0.0096	1.8079	0.0002
Waste management and remediation services	5.6359	0.1703	5.4568	0.0086	0.0002
Real estate	4.3147	4.2207	0.005	0.089	0

Figure A18: Model output: Municipal solid waste generation from Marion restoration project

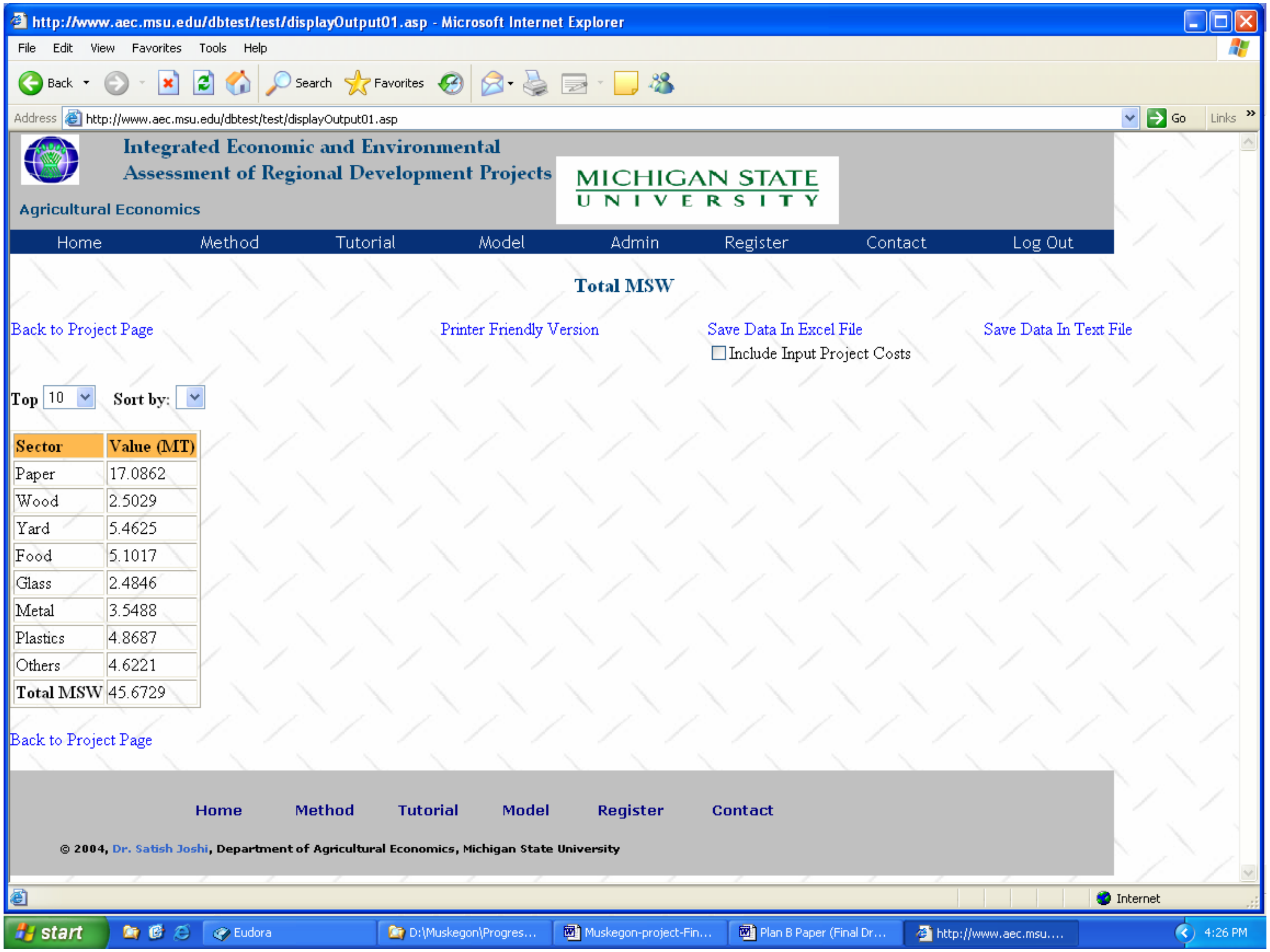
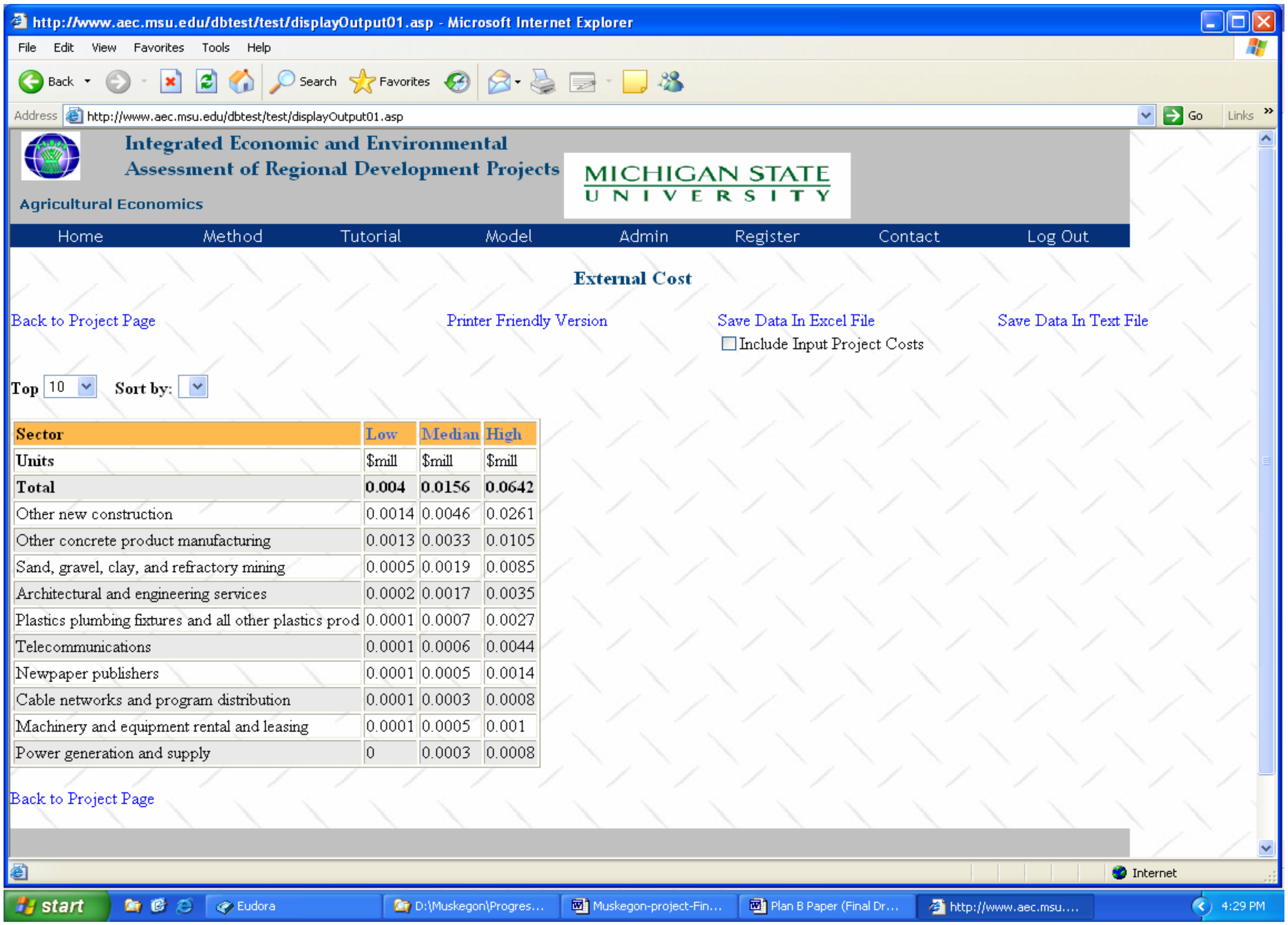
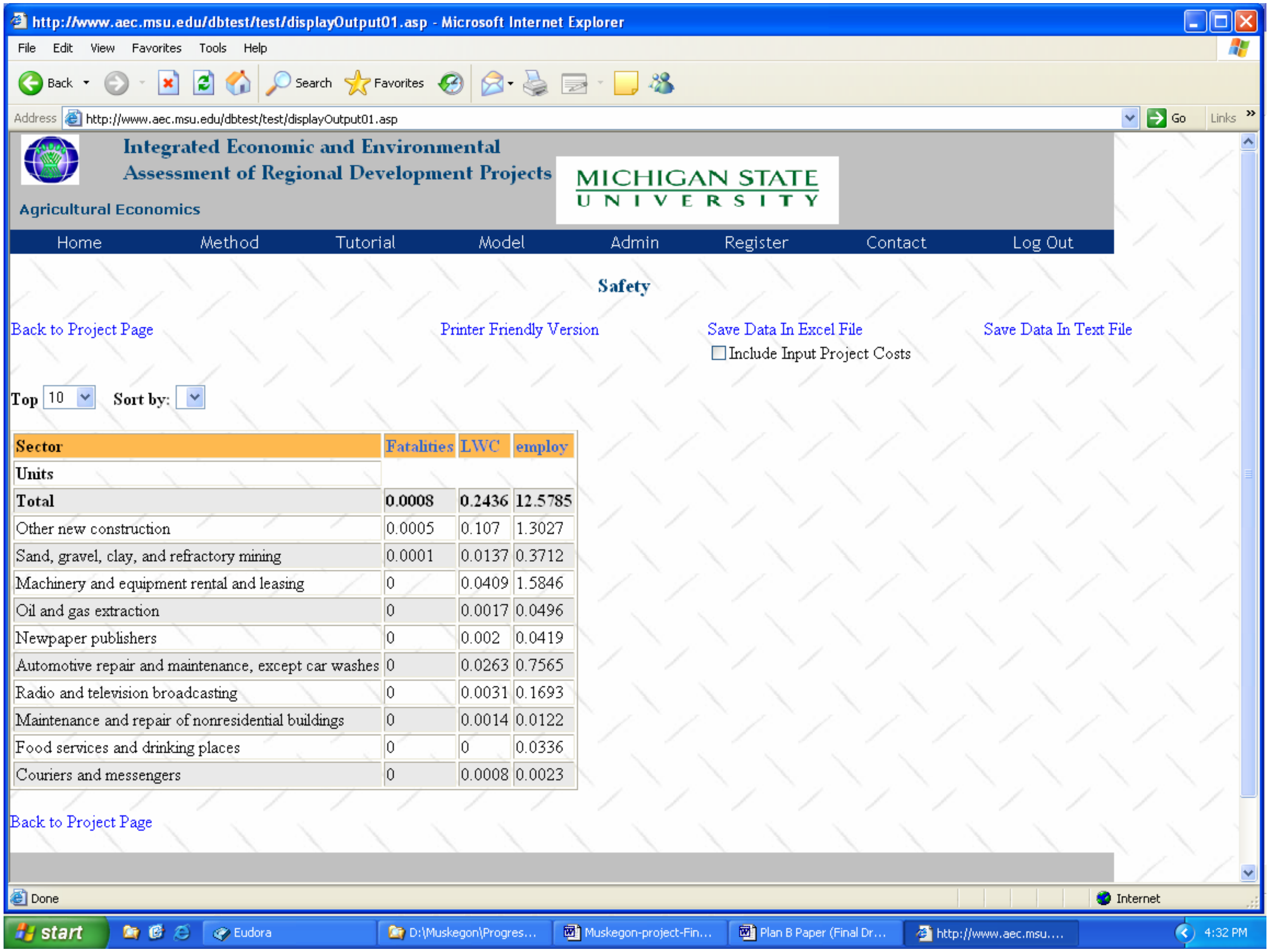


Figure A19: Model output: External cost from Marion restoration project



Sector	Low	Median	High
Units	$mill	$mill	$mill
Total	**0.004**	**0.0156**	**0.0642**
Other new construction	0.0014	0.0046	0.0261
Other concrete product manufacturing	0.0013	0.0033	0.0105
Sand, gravel, clay, and refractory mining	0.0005	0.0019	0.0085
Architectural and engineering services	0.0002	0.0017	0.0035
Plastics plumbing fixtures and all other plastics prod	0.0001	0.0007	0.0027
Telecommunications	0.0001	0.0006	0.0044
Newpaper publishers	0.0001	0.0005	0.0014
Cable networks and program distribution	0.0001	0.0003	0.0008
Machinery and equipment rental and leasing	0.0001	0.0005	0.001
Power generation and supply	0	0.0003	0.0008

Figure A21: Model output: Worker safety impacts from the Marion project



Sector	Fatalities	LWC	employ
Units			
Total	**0.0008**	**0.2436**	**12.5785**
Other new construction	0.0005	0.107	1.3027
Sand, gravel, clay, and refractory mining	0.0001	0.0137	0.3712
Machinery and equipment rental and leasing	0	0.0409	1.5846
Oil and gas extraction	0	0.0017	0.0496
Newpaper publishers	0	0.002	0.0419
Automotive repair and maintenance, except car washes	0	0.0263	0.7565
Radio and television broadcasting	0	0.0031	0.1693
Maintenance and repair of nonresidential buildings	0	0.0014	0.0122
Food services and drinking places	0	0	0.0336
Couriers and messengers	0	0.0008	0.0023